Sewage Research

Studies on the Function of Ripe Sludge*

By H. Heukelekian**

I. The Age of Ripe Sludge as a Factor in Seeding

The value of the use of ripe sludge in seeding sludge digestion tanks has been generally recognized, but the origin of this practice is empirical. It has been known that mixing raw sludge with some of the ripe material reduces the digestion time. Until recent years this empirical practice was accepted without a real understanding of the fundamental nature of seeding. The only criterion was that it gave good results, but little thought was given to the possible means of improving the existing conditions or of remedying defects in the action of the ripe sludge. Even at present we are far from being able to evaluate definitely all of the factors responsible for its beneficial action. Whenever we are able to analyze completely these factors we should be able to improve the existing usage of ripe sludge or supersede this more or less wasteful way of seeding.

Recent studies of Rudolfs, *et al.*,[3] have established the relation between seeding and time of digestion. It has been shown that with 2 per cent daily addition of fresh solids to the ripe sludge a 40-day digestion schedule can be maintained at 70° F. Experience has shown that it is better to base seeding proportions on volatile matter rather than on solids, since the ash content of the raw and ripe sludges at different places varies. The underlying thought in this precaution is that there is a definite relation between the gross volatile matter of the ripe sludge and that of the fresh solids. These deductions as to the proper ratio of seeding have been checked many times both under laboratory and plant conditions and have been universally accepted. From a theoretical standpoint Fischer[2] has shown that it is not the gross volatile matter that is important in seeding but rather the colloidal particles and the inorganic salts in the liquid portion of the sludge.

No definite evaluation of the buffer value and of the inoculating value of ripe sludge can yet be made. We accept the fact that both are effective, but as to the relative importance of the two we are prone to follow our own trends of thought. It is hardly conceivable that ripe sludge should con-

* *Journal Series Paper, New Jersey Agricultural Experiment Station, Department of Sewage Disposal.*

** *Research Bacteriologist, Dept. Sewage Disposal, New Brunswick, N. J.*

tain species that were not present originally in the raw sewage. Furthermore, raw sewage carries such a heterogeneous mass of bacteria that it is probably not a question of the dearth of essential species of bacteria. That the determining factor in seeding with ripe sludge is the numbers of certain species is more probable. With this hypothesis we must assume that these species were present in the original sewage and that if we could make conditions ideal for their development their numbers would no longer be a limiting factor.

The second function of ripe sludge is to furnish to the organisms an ideal environment for their development. It is known that ripe sludge when present in a proper ratio (1:2 on the basis of volatile matter) regulates the pH value. The pH value of a properly seeded mixture of sludge from human sewage drops to 6.8 for only a few days. On the other hand without ripe sludge the pH value of fresh solids drops to 5.0 to 5.2 and stays at this level for a prolonged period (5 to 6 months). The regulation of the pH value of the fresh solids with lime cuts the time of digestion to 3 months, but obviously lime is not so ideal a regulator of the H-ion concentration as is ripe sludge. Lime has a caustic action and may repress certain desirable organisms and stimulate other organisms which are objectionable. If we knew the exact nature of buffers in the ripe sludge we could make a closer approach to the problem. Carbonates and bicarbonates are present in sludges and may combine with ammonia, the decomposition product of nitrogenous substances. Small amounts of phosphates are also present and may give an additional buffering value to the ripe sludge. We do not know the relative importance of the colloidal substances in the liquid portion of ripe sludge. These may be effective by furnishing surface for adsorption or they may combine chemically with the acid substances produced during the decomposition.

Whether we consider the beneficial action of ripe sludge due primarily to its bacterial content or to its buffering effect, there must be a certain stage in the process of ripe sludge formation in which its action is most effective. A green sludge which is in the process of decomposition is a poor seeding material. On the other hand, what is the action of a too-ripe sludge, a sludge that has been stored for five or six months? What is the exact stage of decomposition that will give optimum results for seeding? If this optimum point could be determined, it is reasonable to expect that the organisms actively engaged in decomposition would be present in great numbers and a small proportion of the material might be used as an enriched culture to effect decomposition at a rapid rate.

The following experiments were undertaken for the purpose of throwing some light on these questions.

Methods.—Three sludges of different ages obtained from the separate sludge digestion tanks at Plainfield were used as seeding material. The

first one had been stored for six months in the laboratory, the second for three months, and the third had been freshly drawn from the tank. They were used in seeding the same lot of fresh solids in the ratio of 1:2 on the basis of volatile matter. In the case of the sludge 6 months old the ratio was 1:1.3, *i. e.*, there was a larger proportion of seeding material. The chemical characteristics of the sludges used are given in Table I.

TABLE I

CHARACTERISTICS OF THE RIPE SLUDGES USED

Age	Stored 6 months	Stored 3 months	Freshly drawn
Solids, per cent	5.53	4.92	4.67
Ash, per cent	51.7	48.4	40.4
pH	7.7	7.5	7.35
Alkalinity, p. p. m.	2540	2904	3000
B. O. D. (24 hrs.), p. p. m.	1380	1770	1400
B. O. D. per gm. volatile matter, p. p. m.	510	700	500

Since the moisture contents of the sludges varied it was necessary to take different amounts of each in order to obtain the same amount of volatile matter. The ash content of the freshly drawn sludge was low (40 per cent), indicating a poorly digested sludge. It had a brownish color and was gasifying freely. The alkalinity of the oldest sludge was somewhat lower than the others and the B. O. D. of the sludge stored for three months was somewhat higher than the others. The oldest sludge had the highest pH value; but even the freshly drawn sludge had a pH value of 7.35, which is more alkaline than usual.

Results and Discussion.—Figure 1 shows very striking differences in the rate of gas production in these three tests. The mixture of the fresh solids and sludge that had been stored for 3 months produced gas normally. The peak (50 cc. per day) was attained in 17 days after which the rate began to drop until a low level was reached in 27 days. The freshly drawn sludge did not give such a clear cut peak of gas production. The gas production fluctuated between 20 and 30 cc. per day per gram of raw volatile matter for the first 30 days of digestion, after which it dropped to a low level. The mixture with sludge that had been stored for 6 months had a very low rate of gas production for the first 10 days which increased very gradually to the maximum rate (30 cc. per day) in 28 days and dropped to a low level again in 48 days. Thus the sludge that was stored for 6 months required the longest time for the completion of gasification, but the 3-months-old sludge required a shorter time than that freshly drawn.

The total volume of gas produced per gram of raw volatile matter added was greatest in the mixture with the freshly drawn ripe sludge (Table II).

The two old sludges gave nearly the same volume of gas per gram of raw volatile matter added. The reduction of volatile matter was highest in the mixture with freshly drawn sludge and lowest with the oldest sludge mixture. When we consider the gas production per gram of total volatile matter destroyed, practically equal volumes were obtained for the freshly drawn sludge and the one stored for 3 months, but the 6 months old sludge mixture gave lower results.

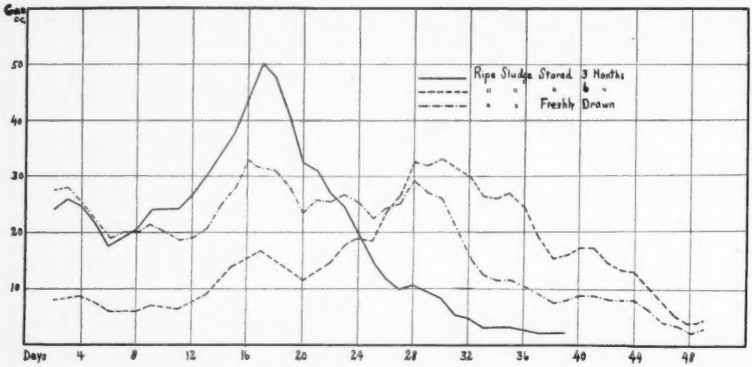


FIG. 1.—The Rate of Gas Production (Cc. Per Gram of Raw Volatile Matter Added) from Mixtures Seeded with Ripe Sludge Stored for Different Periods (Moving Averages of 3).

It will be remembered that the mixture with the oldest sludge had a greater amount of seeding material in proportion to the amount of fresh solids. In spite of this initial advantage it was the slowest in digestion. It gave the least amount of gas and the smallest percentage of volatile matter reduction. The freshly drawn sludge, on the other hand, had a shorter digestion time than the 6 months old sludge but a longer one than

TABLE II

EFFECT OF AGE OF RIPE SLUDGE ON THE YIELD OF GAS AND OF VOLATILE MATTER REDUCTION

	Ripe Sludge 3 Months Old	Ripe Sludge 6 Months Old	Ripe Sludge Freshly Drawn
Total gas, cc	24,710	23,195	29,500
Gas per g. raw volatile matter added, cc.	790	740	940
Gas per g. of volatile matter reduced, cc.	1,370	1,140	1,380
Days for completion	27	48	37
Reduction volatile matter, per cent	40.7	37.0	48.0

the 3 months old one. The yield of gas per gram of raw volatile matter added was highest with the freshly drawn sludge mixture. The reduction of volatile matter was also high and hence the gas produced per gram of volatile matter destroyed was equal to that of the 3 months old sludge. The high gas yields and greater percentage of volatile matter destruction

would indicate that the freshly drawn sludge was not fully decomposed. From the percentage reduction of volatile matter and the difference in gas production it may be concluded that the addition of fresh solids to an incompletely digested sludge retards the time of digestion. When the sludge is neither too old nor too fresh the shortest time of digestion is obtained.

The percentage reduction of volatile matter in the mixture seeded with the 6 months old ripe sludge was low because the ripe sludge itself underwent little decomposition and nearly all the gas came from the fresh solids added. The reduction of volatile matter in the mixture seeded with the 3 months old sludge was only a little higher than that seeded with the 6 months old sludge.

The reduction of volatile matter was 30 per cent greater in the mixture seeded with freshly drawn sludge than in the one seeded with 6 months old sludge. The gas yield from the former was 27 per cent greater than from the latter. The volatile matter content of the ripe sludge used for seeding

TABLE III

CHARACTERISTICS OF THE RIPE SLUDGES USED

Age	Stored 8 months	Stored 2 months	Stored 1 week
Solids, per cent	5.5	4.1	6.67
Ash, per cent	53.1	50.0	50.0
Alkalinity, p. p. m.	1660	3400	3400
B. O. D. (24 hrs.), p. p. m.	1550	1700	1810
B. O. D. per g. vol. matter, p. p. m.	600	850	545

was 25 per cent greater in the freshly drawn sludge than in the 6 months old sludge. Thus the additional gas yield and the greater volatile matter reduction in the mixture with the freshly drawn sludge were due to the decomposition of the so-called "ripe" sludge which in itself was responsible for the retardation of digestion.

None of the results of chemical analysis of the ripe sludge presented in Table I is helpful in determining the seeding value of the sludge. The low ash content of the freshly drawn sludge led us to believe, before the experiment was started, that it would cause a retardation of digestion. This expectation was realized but, on the other hand, two other sludges with nearly similar ash contents gave dissimilar results. The determination of the exact optimum point in the stage of decomposition of sludge will be dealt with in the following paper of this series.

In order to check our results the experiment was repeated. After a lapse of two months, part of the oldest sludge and part of the freshly drawn sludge used in the previous experiment were used again for seeding. A new lot of ripe sludge was obtained from the plant and stored for a week in the

laboratory before being used for seeding. The chemical characteristics of these sludges are given in Table III. No significant changes had taken place in the sludges used in the previous experiment during two additional months of storage. The solids and ash content as well as the biochemical oxygen demand of the oldest sludge remained constant; alkalinity dropped considerably. There was a considerable increase in the ash content of the sludge that was freshly drawn for the previous experiment. The freshly drawn sludge for this experiment which was stored for a week had 50 per cent ash content. In this series, therefore, we had three sludges with practically identical ash contents and as nearly alike in their chemical characteristics as possible. The main difference between them was the time that had elapsed since they were drawn from the tank.

These three sludges were seeded with the same lot of fresh solids on the basis of 1:2 ratio.

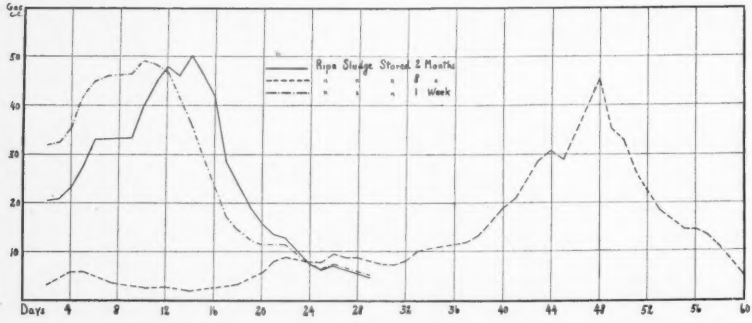


FIG. 2.—The Rate of Gas Production (Cc. Per Gram of Raw Volatile Matter Added) from Mixtures Seeded with Ripe Sludge Stored for Different Periods (Moving Averages of 3).

As is apparent from the daily gas production curves in Figure 2, the mixture with the 8-months-old sludge gasified at a very slow rate. The additional storage for two months impaired the seeding value of this sludge to a considerable extent. In the previous series this same sludge (6 months old) showed a slow and gradual increase in the rate of gas production after 12 days, whereas in the present series the rate of gas production was at a standstill for 18 days (2.5 to 5.0 cc. per gram of raw volatile matter per day) after which it increased only gradually. The peak of gasification was reached in 48 days and completed in 60 days. The seeding ratio in the previous series for this sludge was 1:1.3 whereas in the present it was 1:2. Although this might explain to some extent the greater retardation in the rate of gas production, it seems more probable that actual deterioration had taken place in the seeding ability of this sludge during the two additional months of storage.

The mixtures seeded with the 2-months and 1-week-old sludges gave the normal type of gas production curves. Starting with moderate rate of gas production (20 to 30 cc. per gram of raw volatile matter per day), within 10 to 14 days the peak of gas production was attained, and within 25 days a low level was reached. The mixture seeded with the 1-week-old sludge showed a slight advantage of 2 to 3 days throughout the period of digestion. In comparing this mixture with that made with freshly drawn sludge in the previous series, striking differences may be noted in the rates of gas production. Both sludges were freshly drawn but the former had an ash content of 40 per cent whereas the latter had an ash content of 50 per cent. When the sludge with 40 per cent ash content was stored for two months a marked improvement in its seeding quality had taken place. During this time the ash content had risen to 50 per cent.

There are no significant differences in the yields of gas (Table IV).

TABLE IV

EFFECT OF AGE OF RIPE SLUDGE ON THE YIELD OF GAS AND VOLATILE MATTER REDUCTION

	Ripe Sludge 8 Months Old	Ripe Sludge 2 Months Old	Ripe Sludge 1 Week Old
Total gas, cc	22,810	21,180	23,395
Gas per gram raw volatile matter, cc	760	710	780
Gas per g. volatile matter reduced, cc	1,250	780	1,330
Days for completion	60	25	25
Reduction of volatile matter, per cent	40.6	60.5	39.2

The mixture with the 2-months-old sludge gave a considerably greater reduction of volatile matter than the other two sludge mixtures. It is not possible to say whether this difference is significant or due to experimental error. If it is significant, then the yield of gas per gram of volatile matter reduced is lower with this mixture than with the other two.

It would seem, therefore, that for seeding purposes the best sludge is that which has just completed its digestion but which has not been stored too long after the digestion is completed. With Plainfield solids containing 75 per cent volatile matter this optimum stage is attained when the ash content is about 45 to 50 per cent, or when about 35 per cent reduction of the original volatile matter content has taken place. In plants where the volatile matter content is low, because of industrial wastes or large amounts of grit a smaller percentage reduction of volatile matter will take place. In order to illustrate this point data from three typical plants are given in Table V. The first two sludges are from separate sludge digestion tanks and the last is from Imhoff tanks. The fresh solids from Plainfield and Baltimore have nearly the same volatile matter content (75 and 73 per cent, whereas the solids from Trenton have a much lower volatile matter

content (58 per cent) because of large amounts of trade wastes (mainly iron pickling liquors). The volatile matter content of the ripe sludges obtained from Plainfield and Baltimore are 54 per cent whereas that from Trenton is 45.5 per cent. The percentage reduction of volatile matter decreases with the lower volatile matter content of the fresh solids. If we considered only the percentage of volatile matter in the ripe sludge we would draw erroneous conclusions as to the stage of decomposition of the sludge and its value for seeding. But when the reduction is calculated on the basis of units or equal weights of volatile matter for the different sludges the reduction is nearly the same for all. Starting with 100 g. of volatile matter in each case, from 36 to 38 g. have to be decomposed before the digestion is completed.

TABLE V

VOLATILE MATTER CONTENT OF RAW AND RIPE SLUDGES IN DIFFERENT PLANTS

	Plainfield, Per cent	Baltimore, Per cent	Trenton, Per cent
Volatile matter in raw sludge	75	73	58
Volatile matter in ripe sludge	54	54	45.5
Reduction of volatile matter	28	26	22
Reduction of volatile matter on basis of 100 g. of volatile matter	37	36	38

In starting new tanks or in the operation of old tanks, due consideration must be given to the age of ripe sludge used. If the sludge storage capacity of a digestion tank is large, then it is reasonable to expect that the oldest part of the accumulated sludge may not have the same seeding value as the ripe sludge produced more recently. Although this may be true, the advantages to be gained from a large digestion capacity are such that a partial deterioration of the seeding value of the sludge itself may be readily overlooked. The larger mass of sludge present will counterbalance the poor seeding value of a part of it.

In starting a new tank it sometimes happens that the sludge from an old abandoned tank is available. It is not reasonable to expect as good results with this sludge if it has been stored for a considerable length of time. It will be advisable, in the absence of a better sludge, however, to start the tank with this sludge, since the time necessary to complete digestion even with a seeding sludge that has been stored for eight months is only a fraction of the time required to produce ripe sludge from fresh solids.

Summary and Conclusions.—Sludges were obtained from the separate sludge digestion tanks at Plainfield and stored for different lengths of time in the laboratory before they were used for seeding. The results indicate that:

1. The age of sludge (period of storage or rest) affects the rate of decomposition and gasification of the solids added to it.

2. A sludge that has been stored longer than three months at 20° C. begins to lose its seeding value rapidly.

3. For seeding purposes that sludge is best which has attained its complete decomposition (maximum reduction of volatile matter) but has not been stored too long.

4. Irrespective of the initial volatile matter content of the fresh solids nearly the same amount of volatile matter must be decomposed (roughly 40 per cent) before decomposition is complete.

5. In addition to the ash content of the sludge it is necessary to know the history of the sludge (period of storage) before its value for seeding can be determined.

II. The Optimum Stage of Decomposition of Ripe Sludge for Seeding

The ripe sludges used for seeding in the experiments described in the first paper of this series were obtained from the digestion tanks in Plainfield at different times. The actual stage of decomposition of the sludges was revealed merely by the ash content. Although interesting information was gathered by comparing these various sludges, it was considered advisable to use the same ripe sludge and fresh solids mixture uniformly for the seeding at different intervals. From the results obtained, a more accurate determination of the optimum stage of decomposition of the sludge for seeding purposes was expected.

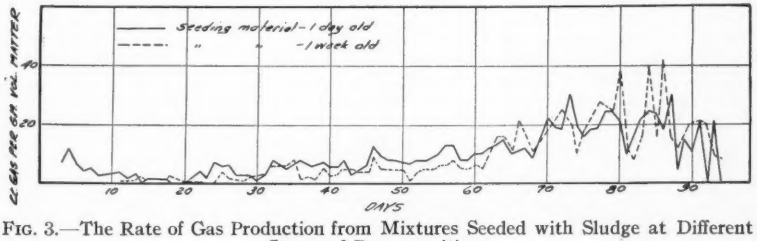


FIG. 3.—The Rate of Gas Production from Mixtures Seeded with Sludge at Different Stages of Decomposition.

Methods.—A large quantity of ripe sludge and fresh solids was mixed (1:2 on the basis of volatile matter). At different intervals a part of this mixture was withdrawn and used for seeding a new lot of fresh solids. The volatile matter content of the stock mixture was determined and the seeding based on the volatile matter content of this material at different intervals. In this way, allowance was made for the reduction of volatile matter. All volatile matter in the digesting material was considered "ripe" although the mixture was not ripe during the first three weeks. Daily gas measurements and initial and final determinations of volatile

matter were made on the mixtures seeded from this stock mixture. All mixtures were incubated at 80° F.

Results.—The daily volume of gas obtained from the different mixtures seeded with the original ripe sludge and fresh solids mixture, after different periods of incubation, are represented in Figures 3, 4, 5 and 6. When the volume of gas produced per day decreased to a level of 10 cc. per gram of raw volatile matter, the digestion was considered completed. This value was selected arbitrarily in order to compare the digestion of the various mixtures.

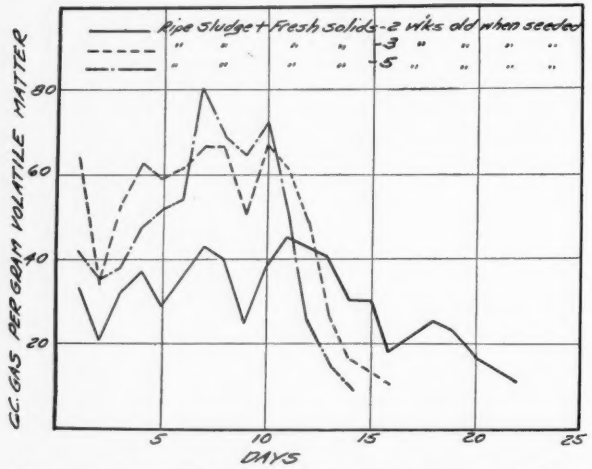


FIG. 4.—The Rate of Gas Production from Mixtures Seeded with Sludge at Different Stages of Decomposition.

The digestion of the mixture seeded with the original ripe sludge and fresh solids mixture incubated for one and seven days was extended over a period of 95 days (Figure 3). For the first two months the evolution of gas was extremely slow. It then gradually increased, with occasional fluctuations, but the largest volume of gas evolved per day was not more than 40 cc. per gram of raw volatile matter added. The average was closer to 20 cc.

When the seed mixture had been incubated for two weeks the digestion time was reduced to 22 days. The daily volume of gas fluctuated between 30 and 40 cc. throughout the major part of the digestion until it was finally reduced. A further reduction in the time of digestion was obtained by seeding with sludge which had digested for three and five weeks (Figure 4). The digestion time with these mixtures was 16 and 14 days, respectively.

With such a brief digestion time the rate of gas production was high, reaching a maximum value of 80 cc. per day.

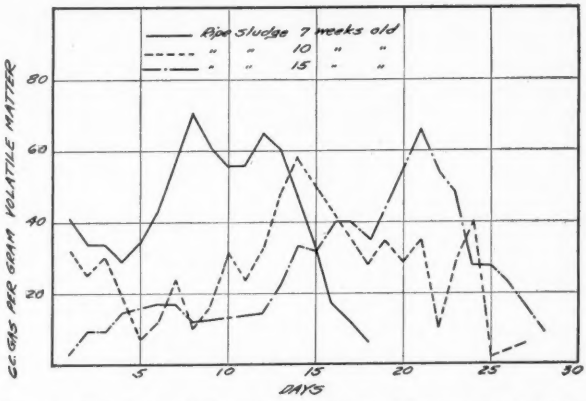


FIG. 5.—The Rate of Gas Production from Mixtures Seeded with Sludge at Different Stages of Decomposition.

No further reduction of the time of digestion of the mixture could be obtained by increasing the incubation period of the seed sludge to seven weeks (Figure 5). The digestion time actually increased slightly. Although only 17 days were required for the mixture to digest when seeded with the 7-weeks-old sludge, 25 days were required when the period of incubation of the sludge had increased to 10 weeks, and 28 days with 15-weeks-old sludge.

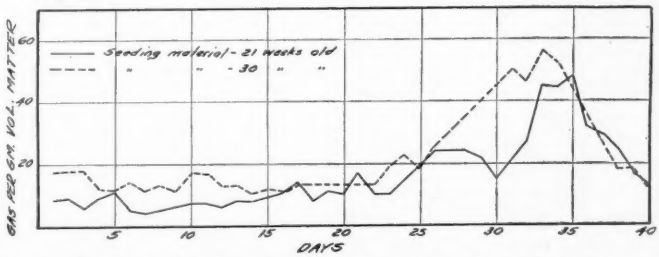


FIG. 6.—The Rate of Gas Production from Mixtures Seeded with Sludge at Different Stages of Decomposition.

Sludge over 20 weeks old digested very slowly for the first 25 days and the digestion was completed only after 40 to 42 days (Figure 6).

The volatile matter reduction and the yield of gas from the mixtures seeded with sludge of various ages are given in Table VI. The volatile

TABLE VI

VOLATILE MATTER REDUCTION AND GAS PRODUCTION FROM THE MIXTURES SEEDED WITH SLUDGE OF VARIOUS AGES

Age of Sludge	Volatile Matter Reduction, Per cent	Gas per Gram Volatile Matter Added, Cc.	Gas per Gram Volatile Matter Reduced, Cc.
1 day	44	892.5	1350
1 week	45.9	803.7	1170
2 weeks	43.2	652.8	1010
3 weeks	41.8	762.1	1210
5 weeks	40.1	656.0	1090
7 weeks	38.0	747.9	1100
10 weeks	40.4	708.8	1170
15 weeks	42.7	728.4	1140
21 weeks	42.5	650.7	1020
30 weeks	43.8	...	...

matter reduction is calculated on the basis of the total mixture rather than on the basis of the raw material added, since the seed material itself contained in the first two or three weeks different amounts of undigested material. For this reason the volatile matter reduction and the gas yield per gram of volatile matter added is generally greater for the first two or three mixtures. When the gas yield is calculated on the basis of volatile matter reduced, however, more uniform results are obtained.

Discussion.—In Table VII are given the ash content and volatile

TABLE VII

ASH CONTENT AND VOLATILE MATTER REDUCTION OF THE ORIGINAL SLUDGE MIXTURE USED FOR SEED, AND THE TIME REQUIRED FOR THE COMPLETION OF DIGESTION WITH THE SLUDGE AT DIFFERENT PERIODS

Age of Seed	Ash in Seed, Per cent	Volatile Matter Reduction in Seed, Per cent	Time Required for Complete Digestion, Days
1 day	33.0	..	95
1 week	35.5	15.6	95
2 weeks	41.0	30.2	72
3 weeks	42.8	36.4	16
5 weeks	41.8	36.4	14
7 weeks	46.6	44.0	17
10 weeks	48.2	45.5	25
15 weeks	46.6	46.1	28
21 weeks	46.7	47.0	41
30 weeks	53.5	57.0	42

matter reduction in the original sludge mixture used for seed, as well as the time required for complete digestion when this sludge was used for seed at different periods. In Figure 7 volatile matter reduction and gas production from the original seed-sludge mixture are represented graphi-

cally. The results indicate that the presence of considerable amounts of raw or partially digested material mixed with the sludge causes a marked retardation in the course of digestion.

The ratio of ripe sludge to fresh solids in the mixture made with the 1-day-old stock mixture as seed, was nearer to 1:9 than 1:2, since only $^1/_3$ of this original mixture was actually ripe volatile matter. If the digestion time were a direct function of the actual seeding ratio of ripe material present, then with the seeding ratio of 1:9 the digestion should have been completed in 70 days rather than in 90 to 95 days, considering 16 days as being ample for digestion with a 1:2 ratio. As decomposition

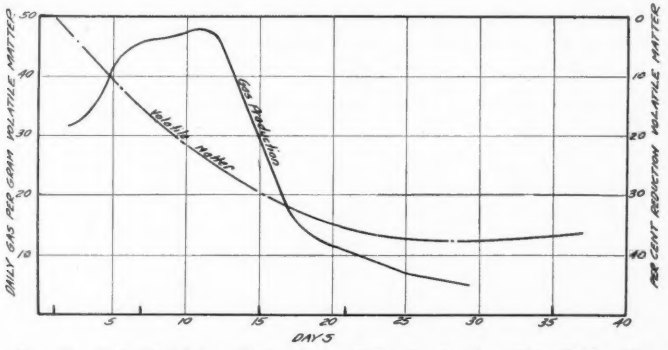


FIG. 7.—Volatile Matter Reduction and Gas Production of the Sludge That Was Used for Seeding Fresh Solids at Different Intervals (the Short Lines on the Abscissae Indicate the Stage of Decomposition at Which the Material Was Used for Seed).

proceeded, the raw material in the seeding mixture was decomposed and the subsequent ratio in the mixtures actually approached 1:2, and the digestion time was reduced. The sludge containing 2 weeks old, partly digested material, in which 30 per cent of the volatile matter was reduced, was still not the optimum for inoculation.

If the beneficial effect of the ripe sludge were due merely to introduction of specific organisms, it was to be expected that the sludge at, or a little after, the peak of gasification (2 weeks old) should contain the maximum numbers of gasifying organisms and should therefore give the best results. Such was not the case. It seems probable that the retarding effect of improper ratio of seeding counterbalanced the beneficial effect of the introduction of large numbers of gasifying bacteria. This would mean that the rate of activity of these organisms is determined to a greater extent by some other factors than their numbers.

It appears from the results that the optimum stage for the use of the ripe sludge is when the rapid decomposition process is completed; when

the gas production is low and maximum volatile matter reduction has taken place (36 per cent).

Storage of sludge for a month after the decomposition is completed does not cause appreciable deterioration in its seeding value, but storage beyond this limit causes rapid deterioration. When digested sludge which has been stored longer than two months is used as seed, there is a prolonged period of retarded activity, the length of which depends on the length of storage. When the food supply is exhausted, the numbers of organisms in the sludge decrease rapidly. On introducing a fresh food supply by the addition of fresh solids, a rapid multiplication of the organisms should take place and decomposition should proceed at a rapid rate.

Summary and Conclusions.—By using the same sludge for seeding purposes at different stages of its decomposition the following facts have been verified:

1. The presence of large amounts of raw material in the sludge retards digestion.
2. The sludge at the peak of decomposition and gasification is not at the optimum for seeding purposes.
3. The optimum stage for seeding purposes is when the decomposition is just completed and for about a month thereafter.
4. Storage of sludge for periods longer than a month after the completion of decomposition impairs its seeding value; the longer the storage the greater the deterioration.

III. Inoculation of Seeded Mixtures with Liquid at Different Stages of Decomposition

If the benefit derived from the addition of ripe sludge is due to the introduction in sufficient numbers of certain species of bacteria, it is to be expected that ripe sludge, at different stages of formation, will act differently. The maximum density of the desirable species of bacteria should occur at the height of decomposition and around the peak of gas formation. But, as has been pointed out in Part II of this series, sludge which is in the process of decomposition, but not fully decomposed, retards the rate of digestion. If we attribute this retardation to the additional load created by the undecomposed portion of the sludge, we must assume that slight fluctuations from the normal seeding ratio (1:2) will retard the rate of digestion; but Rudolfs[4] has pointed out that under certain conditions a 2 per cent daily addition can be extended to 3.5 per cent without lengthening the time of digestion appreciably.

Methods.—A bottle of ripe sludge and fresh solids mixture was inoculated with the liquid portion of 1-week-old digesting mixture and another with the liquid of 2-weeks-old digesting mixture.

The inoculating liquid was drawn at the end of the first week just before the increase in the rate of gas production took place; when the liquid was drawn at the end of two weeks, the peak of gasification had been attained. Thus fresh solids–ripe sludge mixtures were inoculated with portions of material (*a*) previous to the stage of gasification and (*b*) at the height of gasification. The purpose in adding the liquid portion rather than a portion of the total mixture was to avoid adding any appreciable amount of organic matter. It was assumed that the essential organisms would be present in the liquid phase since the major part of activity takes place in the liquid. If the gasifying bacteria attack primarily the liquefied material, we must search for these organisms in the liquid. The amount of inoculum added was 10 per cent of the volume of the mixture to which it was added. If the number of the organisms was a limiting factor, this would insure sufficient inoculation. In each case there was a control to which no inoculum was added. It consisted in the first set of a mixture in the ratio of 1:2 of ripe sludge and fresh solids. The ratio in the second set, which was started a week later, was 1:2.8 on the basis of volatile matter.

Results.—The rates of gas production from the mixture of the two series are presented in Figures 8 and 9 and Table VIII. The addition of

TABLE VIII

GAS PRODUCTION FROM MIXTURES OF RIPE SLUDGE AND FRESH SLUDGE

	Gas per Gram Raw Volatile Matter, Cubic Centimeters	Days for Complete Gasification
Ripe sludge and fresh sludge	755	27
Ripe sludge and fresh sludge and liquid from 1-week-old digesting mixture	750	27
Ripe sludge and fresh sludge	810	41
Ripe sludge and fresh sludge and liquid from 2-weeks-old digestion mixture	810	33

inoculum from the mixture which had been digesting for 8 days did not accelerate the rate of gas production over the control. The addition of inoculum from a mixture which had been digesting for two weeks and which was at that time at the peak of gasification considerably accelerated the rate of gas production over the control. The peak was attained in the inoculated mixture in 26 days while the non-inoculated mixture took 29 days to reach its peak. The final low rate of gas delivery (10 cc. per day per gram of raw volatile matter) was attained in the inoculated mixture in about 33 days and in the non-inoculated in 41 days.

This experiment indicated that the rate of gasification of a properly seeded mixture was considerably accelerated by addition of 10 per cent of liquid (by volume) from a mixture which had reached its peak of gasifica-

tion. When the same amount of liquid was added from the mixture before it had reached its peak of gasification, no such acceleration was ob-

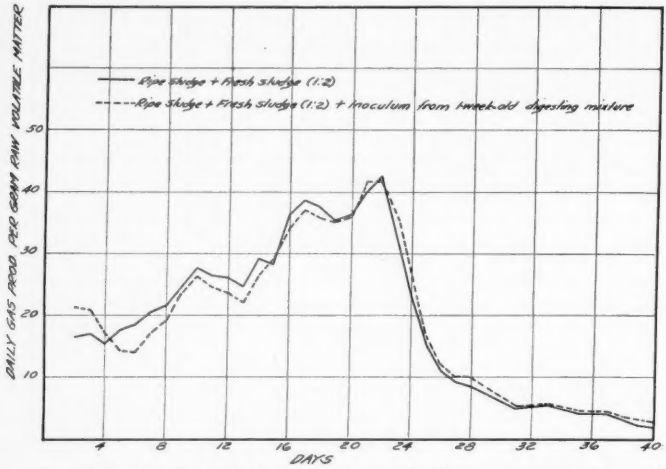


FIG. 8.—The Rate of Gas Production from Seeded Mixtures to Which Liquid from 1 and 2 Weeks Old Digesting Material Was Added.

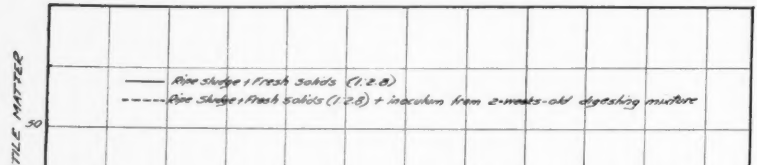


FIG. 9.—The Rate of Gas Production from Seeded Mixtures to Which Liquid from 1 and 2 Weeks Old Digesting Material Was Added.

tained. It would be logical, therefore, to ascribe the acceleration to flora and not to the buffering substance added with the liquid. If such acceleration can be obtained with a mixture which has been properly seeded origi-

nally, it would indicate that ripe sludge is not an ideal carrier of these organisms. However, as we have shown in Part II, ripe sludge at the height of gasification is not at its optimum condition for seeding. The optimum stage for seeding is just after decomposition is completed. It would appear thus that the deleterious action due to seeding with incompletely-digested material overbalances the advantage of a rich gasifying flora. Instead of relying on liquid at the proper stage of gasification as a source of inoculum, we should obtain better results if enough of these organisms were added in artificial cultures to effect a good inoculation. If other conditions, such as buffering and temperature, are also made favorable, then a further improvement in the digestion should be obtained.

Summary.—Inoculation of seeded mixtures of sludge with liquid from other digesting mixtures at different stages of decomposition resulted in considerable acceleration of the rate of gas production when the inoculum was taken for material at the peak of gasification. No acceleration was obtained with inoculum taken from a mixture which was gasifying freely but had not reached the peak of gas production.

IV. Effect of Certain Alkaline Salts on the Digestion of Unseeded and Seeded Fresh Solids

The value of lime for adjustment of the reaction of a poorly-seeded mixture and to hasten the rate of digestion has been well established. It is further recognized that even when the material is properly seeded, the addition of lime accelerates the digestion so that greater amounts of solids can be taken care of without lengthening of the time of digestion.[4]

Fischer[1] found that the addition of sodium nitrate to fresh solids hastened the decomposition and caused a more complete digestion. He states that lime reduced the digestion time from 200 to 100 days, whereas sodium nitrate reduces it to 150 days, thus indicating that lime was superior to sodium nitrate. No such differences are noticeable, however, from the published results. When the digestion is judged by the biochemical oxygen demand, solids and ash results, the material treated with sodium nitrate digested just as well as that treated with lime.

Obviously one of the major functions of ripe sludge is the regulation of the pH of the digesting mixture. The pH value of a properly seeded mixture seldom goes below 6.8 (Plainfield solids), from which it recovers rapidly. The alkaline salts which are present in ripe sludge and which may be instrumental in regulating the pH value are the carbonates and bicarbonates of ammonia, produced as end products of decomposition. It seemed reasonable, therefore, to expect that if these substances were added to fresh solids the pH value could be maintained more or less uniformly and the digestion accelerated. Dipotassium phosphate was included

among these salts because of its well-known buffer action. The experiments described in the following pages deal with the addition of these salts to both fresh solids and fresh solids–ripe sludge mixtures. It was considered advisable to neutralize the initial acidity of the fresh solids with lime and then to add these salts to prevent the pH value from dropping. Accordingly sufficient lime was added to bring the pH value of the fresh solids to 7.2 to 7.4 and then the salts were added in the following amounts per liter of 5 per cent fresh solids:

	Grams per Liter
Ammonium bicarbonate	2.50
Ammonium carbonate	1.25
K_2HPO_4	1.25

Unseeded Solids.—Figure 10 shows the pH values of the untreated and treated fresh solids. It is evident that the initial adjustment of the reaction of the fresh solids by means of lime and the addition of the aforenamed salts have reduced the period of acid digestion from about 65 to 25 days. The reduction of volatile matter in the untreated fresh solids during 72 days was 13.5 per cent. The solids to which lime and the salts were added gave a 24.8 per cent reduction of volatile matter in 56 days.

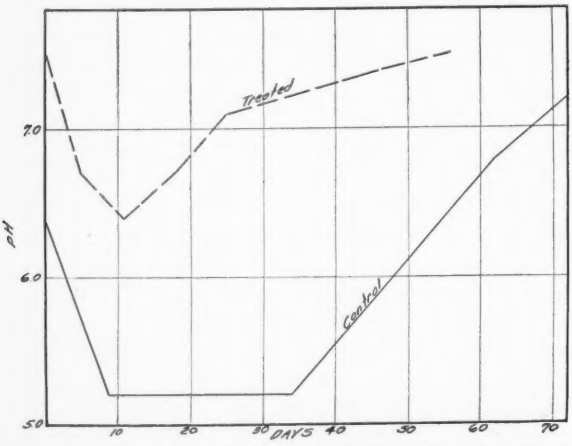


FIG. 10.—pH Values of Untreated Fresh Solids and of Fresh Solids to Which Lime, Ammonium Bicarbonate, Ammonium Carbonate and Dipotassium Phosphate Were Added.

The question naturally arises whether similar results cannot be accomplished by lime alone. An initial adjustment of the pH value of fresh solids with lime is not sufficient to maintain the reaction at neutrality unless large amounts of lime are added, in which case a retardation is

obtained. Frequent adjustments of the pH value, therefore, are necessary when lime is used. In Figure 11 is given a comparison of the pH values obtained by this procedure in contrast with initial liming only and the addition of salts. It required three adjustments with lime before the drop in pH value could be arrested, and the total quantity of lime employed was 7.6 gm. per liter of 5 per cent fresh solids. The quantity of lime used to bring the pH value of the fresh solids up to 7.3 was 3.1 grams per liter. The quantity of the different salts added was the same as given above. Thus it is possible, with a single lime treatment and the addition of salts of this nature, to maintain a neutral reaction more easily than by means of frequent additions of lime. The reduction of volatile matter in 35 days, when the experiment was discontinued, was 20 per cent in both cases.

A comparison of pH values of a single initial lime addition to fresh solids, with addition of lime and alkaline salts, is given in Figure 12. The same quantity of lime was added in both cases (2.2 gm. per liter of fresh solids). The results of untreated fresh solids and solids treated with alkaline salts only are also given. The pH value of the untreated solids was still very low after 30 days (5.6). With lime treatment the neutral point was reached within 30 days. When alkaline salts were used in addition to the lime the pH value dropped to 6.6 and neutrality was reached within less than 6 days. With lime alone the pH value reached the low point of 5.6. When alkaline salts were used without lime the pH value dropped to 5.9 in 4 days and reached the neutral point in about 10 days. The reduction of volatile matter after 47 days was as follows:

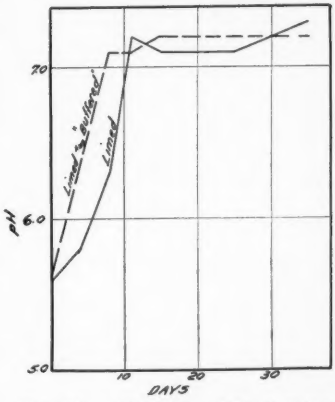


FIG. 11.—pH Values of Fresh Solids Treated with Lime (Repeatedly) and of Fresh Solids Initially Treated with Lime and the Alkaline Salts.

	Per cent
Untreated	33.9
Lime	35.2
Lime and alkaline salts	44.7
Alkaline salts	24.6

The reduction of volatile matter was highest in the solids treated with lime and the buffer salts. A 34 per cent reduction of volatile matter for unseeded and untreated fresh solids in 47 days is high and should be ascribed partially to liquefaction and subsequent volatilization of the liquefied material on drying. It is difficult, therefore, to compare reduc-

tion of volatile matter of two materials in one of which liquefaction, and in the other, gasification has been predominant.

With buffers alone the reduction of volatile matter was less than without treatment or with lime addition, but lime and buffers together gave the highest reduction of volatile matter.

It is evident from the pH curves presented that the addition of the bicarbonate and carbonate of ammonia and of dipotassium phosphate regulates the pH value of the unseeded fresh solids very satisfactorily. Similar results can be accomplished with lime, provided it is applied repeatedly as the reaction becomes acid. Ordinarily this would necessitate four or five adjustments. In contrast to this, if the initial acidity of fresh solids is

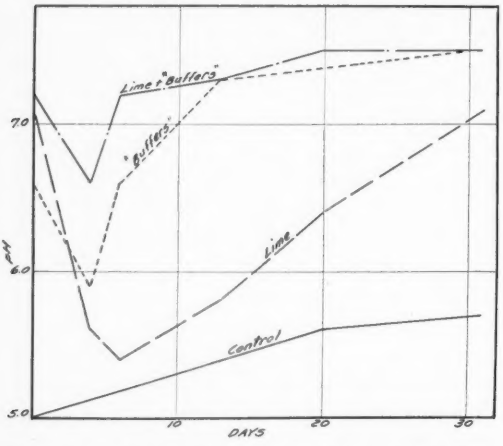


FIG. 12.—pH Values of Fresh Solids Treated with Lime (Initially) and with Lime and Alkaline Salts.

neutralized with lime, and the aforementioned salts are added, the period of acid digestion will be considerably shorter than if the solids were not adjusted or if an initial adjustment with lime were made. The alkaline salts alone, without lime, regulate the pH value better than does a single adjustment with lime.

If these salts or salts of similar nature could be procured at a reasonable cost they would prove of considerable value in starting a new tank and in shortening the period of acid digestion, and consequently ripe sludge could be obtained sooner. The present recommended practice in starting a new tank, where ripe sludge is not available, is to add lime constantly until ripe sludge is produced. This requires enormous quantities of lime, and foaming may occur during this period of adjustment. However, salts of a similar nature as described in the foregoing would obviate the necessity

of constant adjustment of the digesting material with lime. If the daily load of solids is adjusted, the digesting material will not need any further adjustment.

Seeded Solids.—It was considered of interest to determine whether the addition of these alkaline salts would prove beneficial in the digestion of seeded mixtures and whether, as a consequence, the amount of seed could be reduced without affecting the digestion time.

The pH value of the fresh solids was brought up to 7.1 and the following salts were added:

	Grams per Liter
Ammonium bicarbonate	1.6
Ammonium carbonate	0.6
K_2HPO_4	0.6

Two mixtures were made, using the ratio of seeding of 1:2 (on the basis of volatile matter). One of these did not receive any other treatment and the other was treated with the salts as given above. Two other mixtures were made with treated fresh solids, using decreasing ratios of seed, or for given amount of seed increasing the load of fresh solids. Thus in the final mixture the amount of fresh solids in relation to ripe sludge was eight times the quantity in the normal mixture.

It will be seen in Table IX that the digestion of the control mixture

TABLE IX

DIGESTION OF SEEDED MIXTURES TREATED WITH ALKALINE SALTS

Treatment	None	Lime and Buffers	Lime and Buffers	Lime and Buffers	Lime and Buffers
Seeding ratio ripe sludge to fresh sludge on basis of volatile matter	1:2	1:2	1:4	1:8	1:16
Gas produced, cc. per gram of raw volatile matter	800	770	785	735	745
Time for complete gasifications (days)	68	24	41	95	113

(seeded normally but not treated) proceeded very slowly. Gasification in this mixture was completed only after 68 days, whereas normally a mixture seeded in similar ratio and incubated at the same temperature (72° F.) will digest in 30 to 35 days. The fresh solids and ripe sludge were obtained from the Plainfield plant as usual. The ripe sludge contained 7.4 per cent solids and 53.5 per cent ash. The fresh solids contained 4.7 per cent solids and 20.0 per cent ash. They were thus normal in respect to physical appearance and analysis, but it is possible that certain wastes in the fresh solids caused the retardation of digestion.

Whatever might be the explanation, since the same fresh solids and ripe sludge were used for all mixtures in this series, the results should be com-

parable. Thus with the same materials seeded in the same ratio as the control but with the fresh solids treated with lime and alkaline salts, the digestion time was only 24 days, or slightly more than one-third as long as the untreated mixture. The mixture that received only half the amount of seed, but was treated with lime and salts, digested faster than the normally seeded but untreated mixture. Further reducing the amount of seed increased the time of digestion. The yield of gas was not materially affected by the treatment, which would signify that the addition of lime and alkaline salts did not change the type of digestion or increase the degree of decomposition of gas-yielding substances but merely accelerated the rate of their decomposition.

Since the solids used in the preceding experiment were considered to be abnormal on account of the slow rate of decomposition, it was deemed advisable to repeat the experiment with a different lot of fresh solids. The chemicals added were as follows:

	Grams per Liter Fresh Solids
Lime	2.5
Ammonium bicarbonate	2.5
Ammonium carbonate	1.25
K_2HPO_4	1.25

The results of the second trial are given in Table X. The untreated but seeded solids (1:2) digested in 37 days, which is the normal period for Plain-

TABLE X

DIGESTION OF SEEDED MIXTURES TREATED WITH ALKALINE SALTS

Treatment	None	Lime and Buffers	Lime and Buffers	Lime and Buffers
Seeding ratio ripe sludge to fresh sludge on basis of volatile matter	1:2	1:2	1:4	1:8
Gas produced, cc. per gram raw volatile matter	790	675	720	700
Time for complete gasification (days)	37	24	37	50

field solids. When the fresh solids were treated with lime and buffers the digestion was completed in 24 days—an improvement of 35 per cent in contrast with the 65 per cent improvement obtained in the previous series with a similar treatment. A 37-day digestion period could be maintained with half the amount of seed, provided the fresh solids were treated. When the seed was reduced to one-fourth the original quantity the digestion time was 50 days. Thus it appears that the addition of lime and alkaline salts accelerates the rate of digestion of a properly seeded mixture. It is also possible to reduce the amount of seed or increase the load of fresh solids by treating the solids with lime and alkaline salts.

The next step was to determine whether the beneficial effect was at-

tributable to any of the salts added singly or was due to a combination of all. The fresh solids were treated as follows:

	Lime, G.	Ammonium Bicarbonate, G.	Ammonium Carbonate, G.	K_2HPO_4, G.	NH_4Cl, G.
1	0	0	0	0	0
2	2.5	2.5	1.25	1.25	0
3	2.5	0	0	0	0
4	2.5	2.5	0	0	0
5	2.5	0	1.25	0	0
6	2.5	0	0	1.25	0
7	2.5	0	0	0	2.88

Lime plus one of the salts was added in each case except in the control. The same amount of nitrogen in the form of ammonium chloride as was present in the combined bicarbonate and carbonate salts was added in a final mixture. These were all seeded with the same ripe sludge (2:1 on the basis of volatile matter) and incubated at 72° F. Daily gas measurements were made. The condensed results are given in Table XI. It will be

TABLE XI

DIGESTION OF SEEDED MIXTURES TREATED WITH ALKALINE SALTS

Treatment*	None	Lime and Ammonium Bicarbonate	Lime and Ammonium Carbonate	Lime and K_2HPO_4	Lime and NH_4Cl
Gas produced, cc. per gram of raw volatile matter	790	780	695	710	660
Time for complete gasification (days)	37	24	24	24	24

* All mixtures seeded with 1 part of volatile matter in ripe sludge to 2 parts of volatile matter in fresh solids.

readily seen that the addition of lime reduced the time for complete gasification from 37 to 24 days. No further reduction in the time of digestion could be obtained, however, with the addition of the salts in addition to lime. The results seem to indicate that in a highly-buffered mixture, as is the case in a properly seeded mixture, the use of the alkaline salts in addition to lime is superfluous.

Discussion.—In studying the mechanism of the buffer action of ripe sludge, the bicarbonate and the carbonate of ammonia are of prime importance. Ammonia is produced as the end product of decomposition of nitrogenous substances, whereas carbonates and bicarbonates are formed by the action of carbon dioxide. The concentration of these substances increases during the course of decomposition, consequently ripe sludge should contain relatively high concentrations. When these salts in addition to dipotassium phosphate are added to fresh solids which have previously been

neutralized with lime, the pH value does not become sufficiently acid to interfere with digestion, as would be the case if the fresh solids were not treated at all or when merely an initial addition of lime was made. Similar results can be accomplished by constantly adjusting the reaction of digesting fresh solids, but this procedure is both time-consuming and expensive.

When the digesting mixture is properly seeded, the use of the alkaline salts in addition to lime does not bring about any further reduction in the time of digestion than if lime alone were used. It would appear that increasing the alkali reserve beyond a certain limit is of no avail. Ripe sludge is such a strong buffer agent that any further addition of buffers after the neutralization of the fresh solids with lime is superfluous.

The value of these alkaline salts will become obvious when a new tank is to be started and when there is either no ripe sludge or an amount insufficient to give proper seeding. In such cases, the use of these salts, in addition to lime for neutralization of the initial acidity of fresh solids, will regulate the pH value of the digesting mixture and accelerate the rate of digestion so that sufficient ripe sludge could be produced in a comparatively short time to start the normal operation of the tank with ripe sludge alone.

The studies reported in the foregoing indicate that ripe sludge has a two-fold function: it regulates the pH value of the digesting mixture, and it also accelerates digestion by furnishing the necessary flora. When a properly seeded mixture is limed, a further increase in the alkali reserve by the addition of certain alkaline salts does not improve digestion. But when to a properly seeded mixture liquid from a mixture at the peak of gasification is added an acceleration in the rate of digestion ensues.

Fresh solids are deficient in both properties—seeding and buffering. Seeding with ripe sludge accelerates the rate of digestion of fresh solids. If without the ripe sludge the alkaline salts are added to fresh solids, the pH value is well regulated and digestion accelerated. Can ripe sludge be completely eliminated with the use of these alkaline salts and an inoculum of proper organisms?

Subsequent studies will deal with the combination of proper artificial seeding materials with buffers in the digestion of fresh solids without ripe sludge.

Summary.—The neutralization of the initial acidity with lime and the addition of the carbonates and bicarbonates of ammonia and dipotassium phosphate to unseeded fresh solids regulates the pH value of material so that the acid period of digestion is materially reduced in comparison with the untreated fresh solids or fresh solids that have been treated initially with lime. The regulation of the pH value accomplished by the addition of these alkaline salts compares favorably with the maintenance of pH value by the repeated addition of lime.

In properly seeded and limed mixtures the addition of these salts is of

no further benefit because the pH value is already regulated by the ripe sludge and the lime.

References

[1] A. J. Fischer, W. Rudolfs, and P. J. A. Zeller, "Effect of Alkaline Substances on Sewage Sludge Digestion," N. J. Agr. Expt. Sta., *Bull.* **474,** pp. 3–18, 1929.

[2] A. J. Fischer, "Some Factors Influencing the Decomposition of Sewage Sludge," to be published in THIS JOURNAL.

[3] W. Rudolfs, *et al.*, "Fourth Annual Report Department of Sewage Disposal," N. J. Agr. Expt. Sta., *Bull.* **427,** pp. 74–86, 1926.

[4] W. Rudolfs, *et al.*, "Fifth Annual Report Department of Sewage Disposal," N. J. Agr. Expt. Sta., 1927.

Report of the Water Pollution Research Board for the Year Ended June 30, 1929.—Department of Scientific and Industrial Research. H. M. Stationery Office, 1930. 28 pages. Illustrated. 9*d.* net. The work on sewage and stream pollution which is being carried out by the Department includes: (1) A scientific survey of the River Tees. The investigation, which began in April, 1929, has been divided into three parts, a biological and chemical survey of the tidal reaches, a hydrographical survey of the tidal reaches and a biological and chemical survey of the non-tidal reaches. (2) Sewage disposal. An investigation of the biological changes which occur in the activated sludge process is proceeding. (3) Beet sugar factories' effluents. The investigation of the treatment of effluents by biological filtration, carried out in co-operation with the industry, has been continued. The processes employed at beet sugar factories, the nature and quantities of the waste waters, and the possibilities of recirculation and reuse of the waters are discussed. The investigations have shown that a high degree of purification can be achieved by treatment of the effluents by biological filtration. An experimental filtration plant, which is described and of which diagrams are given, was operated at Colwick Beet Sugar Factory during the campaigns of 1927–8 and 1928–9, and the biological process of purification investigated also by laboratory experiments at Rothamsted Experimental Station.

As the survey of the River Tees only began in April, 1929, the work so far has been mainly preparatory. Accounts are given of the work of the Research Sub-Committee of the Institution of Gas Engineers on liquor effluents from gas works, of the Beet Sugar Factories Committee, of the Royal Sanitary Institute, and of the Association of Managers of Sewage Disposal Works.—Excerpts from Abstract **841,** *British Summary of Current Literature, Water Pollution Research*, Vol. III, **7,** July (1930).

The Influence of Chlorine on Sewage Sludge Digestion

BY C. E. KEEFER* AND HERMAN KRATZ, JR.**

The ever-increasing use of chlorine as an adjunct in sewage treatment has brought to the fore the question of the effect, if any, of chlorine on the digestion of sewage sludge. This question was studied by Fair and Carlson,[1] who reported that the pre-chlorination of settling sewage will apparently result in more rapid production of methane during the earlier

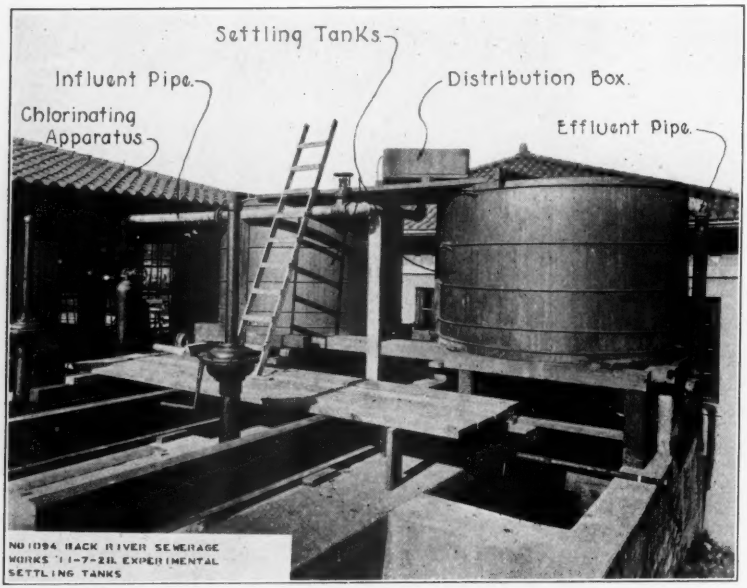
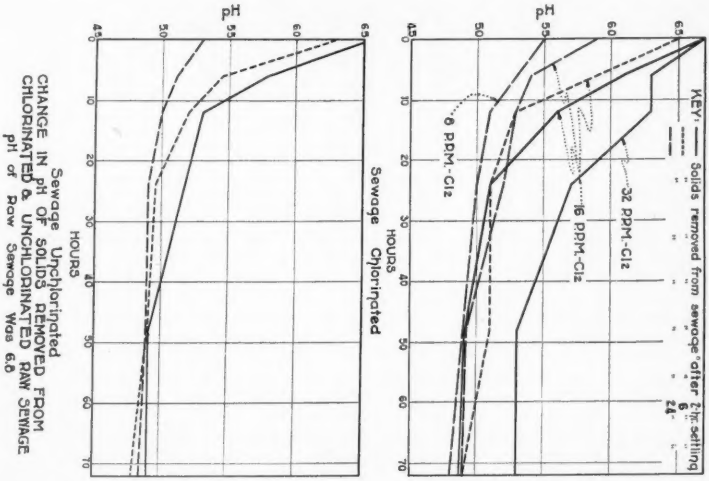


FIG. 1.—Equipment Used for Collecting Solids from Chlorinated and Unchlorinated Sewage.

stages of digestion, but that the ultimate yield will be slightly lower than if the sewage were not chlorinated. Chlorine is being used to treat raw sewage as it flows through long outfalls in order to retard septic action. Moreover, the chlorination of raw sewage as it reaches sewage works is being practised as an odor control measure. Other investigators have also reported on the advantages to be derived from raw sewage chlorina-

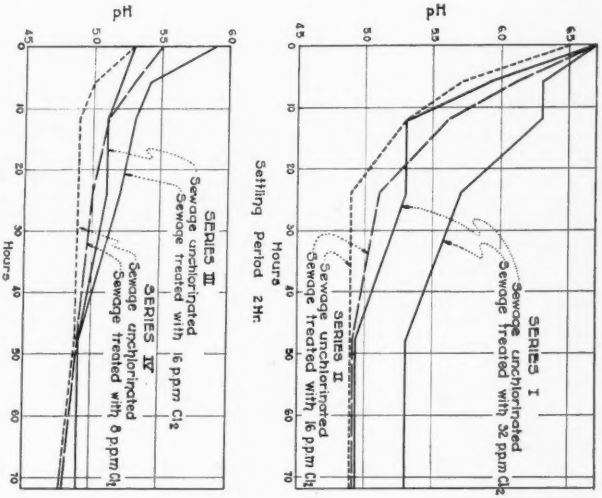
* *Engineer of Sewage Disposal.*
** *Junior Chemist, Bureau of Sewers, Baltimore, Md.*

tion in order to reduce the oxygen demand and to relieve the foaming of Imhoff tanks. In order to learn what effect the chlorination of raw



CHANGE IN pH OF SOLIDS REMOVED FROM CHLORINATED & UNCHLORINATED RAW SEWAGE
pH of Raw Sewage Was 6.8

FIG. 2.



CHANGES IN pH OF SOLIDS REMOVED FROM CHLORINATED & UNCHLORINATED RAW SEWAGE WHEN SETTLED FOR 2 & 24 HR.
pH of Raw Sewage was 6.8

FIG. 3.

sewage would have upon the digestion of the solids present, an extended group of experiments was made at the Baltimore sewage works. The results of this investigation indicated that on the whole no detrimental

effects were noticeable, and that a hastening of sludge digestion could generally be expected.

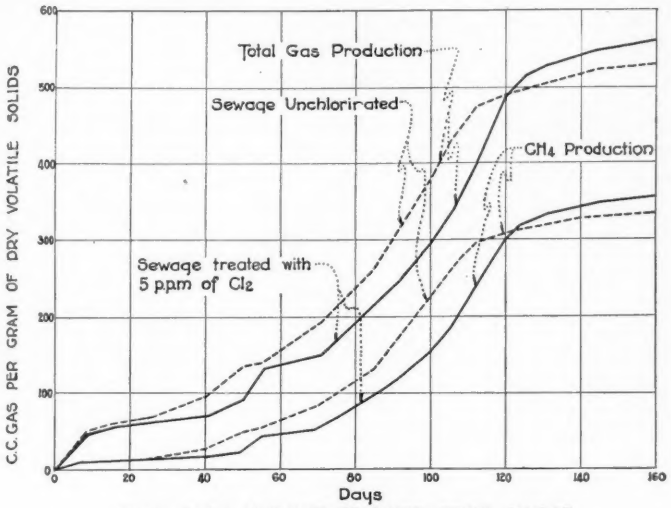
Method of Conducting Experiment

Two wood-stave settling tanks (Figure 1) with conical bottoms, 8 ft. in diameter and 5 ft. deep, each with a capacity of 880 gal., were provided. Raw sewage, which was domestic in character, and which had passed through bar screens with $^7/_8$-in. openings, was pumped through a small distribution box into each tank. The flow in each was made as far as possible the same. Chlorine gas in pre-determined amounts was applied from a solution-feed chlorinator to the sewage as it entered one of the tanks. The sewage flowing to the second tank was untreated. At the end of a definite period of time the solids which had settled in the bottom of the tanks were drawn off for subsequent study and analysis.

The purpose of the experiment was two-fold: first, to learn the effect of chlorination on the subsequent change in the pH value of sewage sludge; and secondly, to compare the rate of digestion of chlorinated and unchlorinated solids. It was believed that the pH value of sewage solids would decrease at a slower rate from chlorinated than from unchlorinated sewage. A number of tests were made to check this hypothesis. Solids were collected in each of the above-mentioned settling tanks for 2, 6 and 24 hrs. at the end of which periods the sludge was drawn off. The pH value of the materials was determined at frequent intervals for a period of three days.

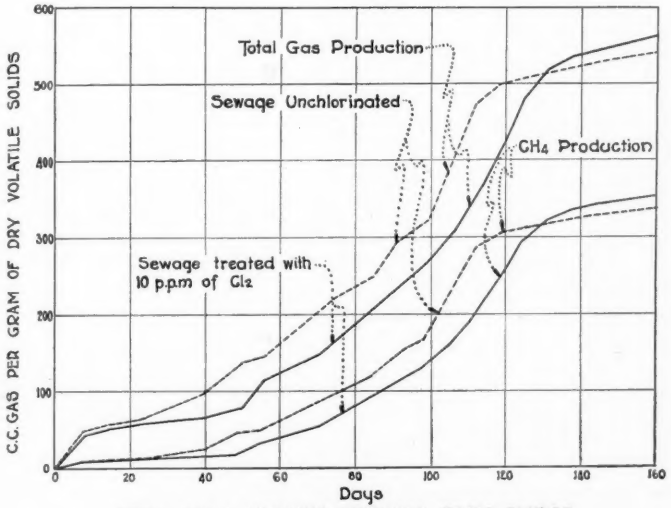
The results are shown in Figures 2 and 3. Figure 2 shows that the longer fresh chlorinated solids are allowed to remain in a settling tank before they are removed, the lower their pH value will be. The solids which were in the settling tank two hours had a pH value of 6.7, whereas the solids removed at the end of 24 hrs. had a pH value of 5.5 in one case and 5.9 in the other. It is also apparent that chlorine had a marked effect in retarding a drop in the pH value. The pH value of solids obtained from sewage treated with 32 p. p. m. of chlorine did not reach 5.5 until 36 hrs., whereas in the case of sewage treated with 16 p. p. m. of chlorine the pH was 5.5 within 12 hours. Figure 2 also shows the characteristic decrease with age in the pH value of solids obtained from unchlorinated sewage.

Figure 3 indicates that the pH value of solids collected from chlorinated sewage drops less rapidly than that of solids obtained from unchlorinated sewage. Such is the case particularly where large quantities of chlorine are used. Since the pH value of sludge should ordinarily be somewhat above 7.0 for rapid sludge digestion, the solids obtained from chlorinated sewage will require less lime additions to control the reaction, or where



TOTAL GAS & METHANE PRODUCED FROM SLUDGE OBTAINED FROM UNCHLORINATED SEWAGE AND ALSO FROM SEWAGE TREATED WITH 5 P.P.M. OF Cl_2

FIG. 4.



TOTAL GAS & METHANE PRODUCED FROM SLUDGE OBTAINED FROM UNCHLORINATED SEWAGE AND ALSO FROM SEWAGE TREATED WITH 10 P.P.M. OF Cl_2.

FIG. 5.

they are mixed with digested sludge, a smaller quantity of this latter material will be needed.

Sludge Digestion Studies

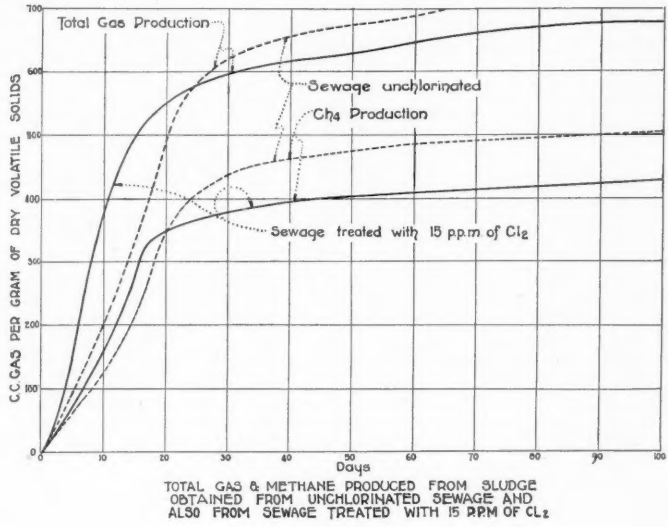
Seven different tests were made, the first in November, 1928, and the last in December, 1929, to see what effect the chlorination of sewage would have upon the speed of sludge digestion. Each test consisted of incubating in 5-gal. carboys a quantity of sludge, a portion of which was obtained from the chlorinated and another portion from the unchlorinated sewage. In order to hasten digestion the raw sludge was mixed with digested material in the ratio of two parts by weight of raw material to one part of digested (both dry basis). This ratio has been used in previous experiments on sludge digestion at Baltimore, and has been followed therefore in these chlorination studies for comparative purposes.

There was some difference in the character of the solids obtained from the chlorinated and the unchlorinated sewage. On the dry basis, the chlorinated material roughly contained 3 per cent less volatile solids and 17 per cent less ether-soluble matter. Furthermore, considerable grease separated from the chlorinated sewage and floated on the surface. This condition was not observed on the unchlorinated sewage. It would seem the chlorine had a tendency to separate a portion of the grease from the solids.

In each instance the solids were incubated at 28° C. ±1°. The degree of digestion was determined by measuring at frequent intervals the accumulated quantities of gas evolved. Analyses were made weekly to find the percentages of CH_4, CO_2, O_2 and H_2. All gas volumes are reduced to 0° C. and 760 mm. of mercury. The quantities of total gas and methane evolved from each of the seven groups of bottles are shown in Figures 4 to 10. Solids were collected from raw sewage, which had been treated with chlorine ranging in amounts from 5 to 25 p. p. m. and also from sewage which was unchlorinated.

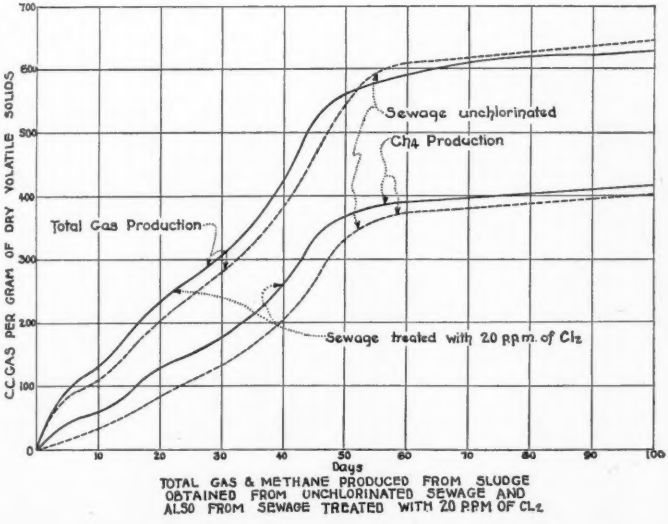
Figure 4 shows that when 5 p. p. m. of chlorine were used gas formation was slightly more rapid from those solids collected from unchlorinated sewage. The same condition was observed (Figure 5) when 10 p. p. m. of chlorine were added. When 15 and 20 p. p. m. of chlorine were applied to the sewage (Figures 6 and 7) the solids obtained from the chlorinated sewage produced gas more rapidly until the decomposition process was about 80 per cent completed.

Additional tests were made using 5 and 10 p. p. m. of chlorine. The results are given in Figures 8 and 9. Figure 8 shows that when 5 p. p. m. of chlorine were used the total gas production from both the chlorinated and the unchlorinated solids was about the same. In this particular instance, considerably more methane, however, was given off by the un-



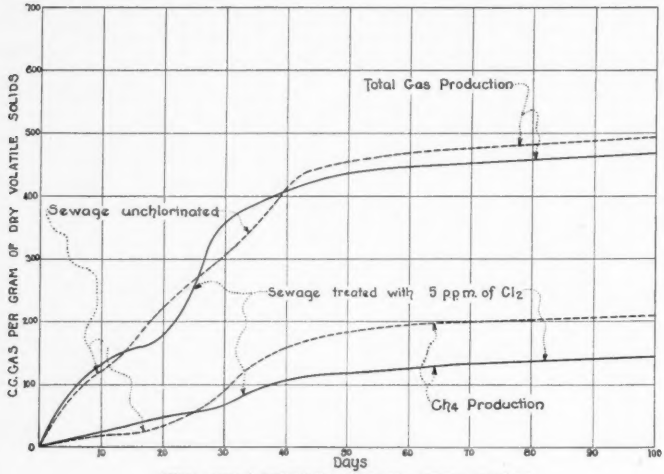
TOTAL GAS & METHANE PRODUCED FROM SLUDGE OBTAINED FROM UNCHLORINATED SEWAGE AND ALSO FROM SEWAGE TREATED WITH 15 P.P.M OF Cl_2

FIG. 6.



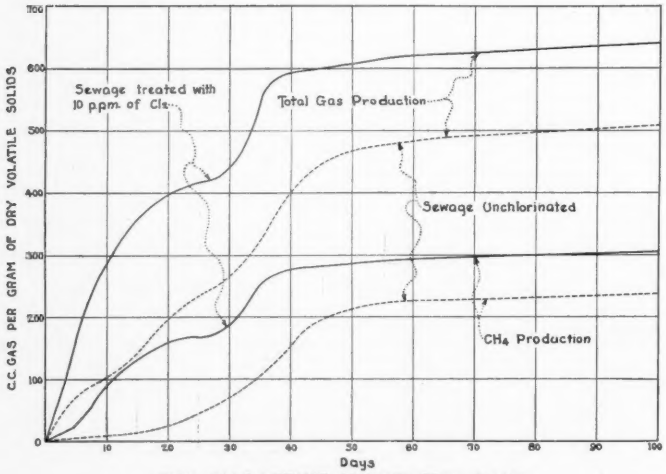
TOTAL GAS & METHANE PRODUCED FROM SLUDGE OBTAINED FROM UNCHLORINATED SEWAGE AND ALSO FROM SEWAGE TREATED WITH 20 P.P.M OF Cl_2

FIG. 7.



TOTAL GAS & METHANE PRODUCED FROM SLUDGE OBTAINED FROM UNCHLORINATED SEWAGE AND ALSO FROM SEWAGE TREATED WITH 5 P.P.M OF Cl_2

FIG. 8.



TOTAL GAS & METHANE PRODUCED FROM SLUDGE OBTAINED FROM UNCHLORINATED SEWAGE AND ALSO FROM SEWAGE TREATED WITH 10 P.P.M. OF Cl_2

FIG. 9.

chlorinated material. When 10 p. p. m. of chlorine was used (Figure 9), the speed of digestion, when measured by the total gas or methane production was very much greater from the chlorinated material. As shown by Figure 10, this result was also obtained when 25 p. p. m. of chlorine was added to produce a residual of not less than 0.3 p. p. m. in the effluent from the settling tank. The settled solids also contained residual chlorine when they were mixed with the digested sludge at the beginning of the digestion period.

Of the seven tests that were made two showed a decided increase in the

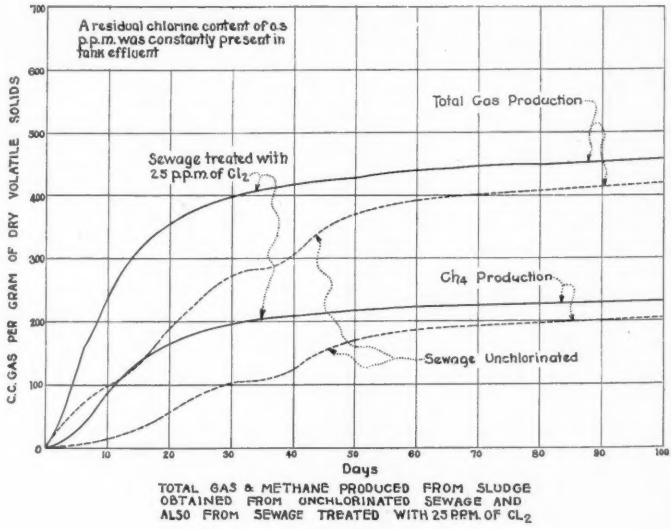

A residual chlorine content of 0.3 p.p.m. was constantly present in tank effluent
Total Gas Production
Sewage treated with 25 p.p.m. of Cl_2
CH_4 Production
Sewage Unchlorinated
C.C. GAS PER GRAM OF DRY VOLATILE SOLIDS
Days
TOTAL GAS & METHANE PRODUCED FROM SLUDGE OBTAINED FROM UNCHLORINATED SEWAGE AND ALSO FROM SEWAGE TREATED WITH 25 P.P.M. OF Cl_2

FIG. 10.

speed of sludge digestion when chlorine was used; two showed a slight increase; one indicated little difference in the digestion of the chlorinated and the unchlorinated solids; and two indicated a slight decrease in the speed of digestion as compared with the digestion of unchlorinated solids. The chlorinated solids produced more total gas in four of the tests and more methane in five of the tests.

Discussion

When raw sewage is treated with chlorine, the pH value of the solids removed by sedimentation does not decrease so rapidly as when chlorine is not used. This conclusion is born out by all of the tests which were made. The evidence as to whether chlorine promotes or retards sludge

digestion is, however, less conclusive. From the work done at Baltimore it seems safe to say that chlorine is not detrimental to sludge digestion and if anything its use is beneficial.

Acknowledgment

The Baltimore Sewage Works is under the general supervision of C. F. Goob, chief engineer, and Milton J. Ruark, sewerage engineer.

Acknowledgments are due to the Wallace & Tiernan Co., who furnished the chlorinating apparatus used in the experiment, to Linn H. Enslow of the Chlorine Institute, who offered helpful suggestions during the course of the work, and to G. K. Armeling and Edward Cromwell, superintendent and principal sanitary chemist, respectively, of the Baltimore sewage works.

References

[1] Gordon M. Fair and C. L. Carlson, "Effect of Chlorination upon the Digestion of Sewage Solids," *Eng. News-Record*, **99**, 1030, Dec. 29, 1927.

Comparison of the Effectiveness and Economy of Mechanical Sewage Treatment Systems, with Special Reference to Gas Production.—PFLEIDERER, E. *Wasser u. Gas*, **1929,** 177 and 233; *Tech. Gemeindebl.*, **1930,** 33, 59. A comparative study is made of the working of the Stuttgart sewage treatment plant, where Emscher, Neustadt and Stuttgart tanks are used to deal with the same sewage under the same local conditions and speed of flow through the clarification tank. All the tanks are covered for gas collection. Details are given for the construction, operation and results of operation of the tanks, the development of gas production and its economic results. The working of one- and two-storied tanks is compared under natural conditions and with artificial heating. Pressure in the deep tank of a two-storied plant gives a sludge with a lower water content than that from a single tank, but drainage and digestion are not thereby improved. Digestion time and, therefore, digestion tank size are the same for the different types. Separate shallow digestion tanks produce more gas than two-storied and are cheaper in construction. Artificial heating is not possible in a two-storied tank because of its effect on the settling process. In separate digestion tanks, every precaution must be taken to avoid loss of heat if the process is to be economically possible.—Abs. No. **822,** *British Summary of Current Literature, Water Pollution Research*, Vol. III, **7,** July (1930).

Sewage Works Operation

Symposium: Standard Methods for the Examination of Sewage and Sewage Sludge

Standard Methods of Water Analysis has frequently been referred to as the Bible of the water chemist. If this be so, the sewage chemist has by necessity added the apocrypha. The rapid development of more complex processes of sewage treatment and sludge digestion during the past ten years has made it necessary for those chemists actively engaged in sewage treatment to develop and modify methods of analysis somewhat different from those printed in *Standard Methods*.

A committee of the American Public Health Association has final jurisdiction over the authorization and publication of *Standard Methods*. This committee receives the coöperation of Committee No. 1 of the American Water Works Association. *Standard Methods* is published by a joint legal agreement between the two associations. A committee of the American Chemical Society coöperates in the preparation of the chemical methods. The A. P. H. A. committee is headed by Edwin O. Jordan, *Chairman*. The last meeting of this committee was held at the October, 1930, meeting of the A. P. H. A. with the following present: E. O. Jordan, *Chairman;* R. G. Perkins, L. M. Wachter, W. H. Frost, A. Wadsworth, W. H. Park, N. MacL. Harris, J. F. Norton, *Secretary*. Dr. Norton's report was published in the *American Journal of Public Health*, Vol. 20, pages 27–33, January, 1930. The reference to sewage examination is as follows:

> "The temperature for drying of solids is now given as 103° Centigrade. In water examination, the standard temperature is 180° Centigrade. This discrepancy should be removed. Probably 180° C. should be adopted for both materials. The inclusion of methods for the determination of total, fixed and volatile sulphides has been suggested. It is not quite clear whether the analytical procedures have been sufficiently standardized to include them at this time. A quantitative procedure for the determination of phenols would seem to be an excellent addition to the present methods. There is no doubt that the presence of these substances in water supplies must be taken into account. Several modifications of the method of Gibbs have been investigated, and I believe that agreement on at least a provisional procedure could be obtained. A very desirable but difficult determination is that of settleable solids in sewages. The standardization of some method such as that devised by Imhoff, or some modification of this, might well be recommended. At present there is little uniformity in such determinations."

Committee No. 1 of the A. W. W. A. is under the chairmanship of Jack J. Hinman, Jr. A very complete annual report of this committee is

published, the most recent being in the *Journal of the A. W. W. A.*, Vol. 22, pages 242–260, February, 1930. Methods of chemical analysis are under the direction of various referees who submit an annual report. This committee is active in the study and recommendation of modified or improved procedures. Their detailed report must be consulted for further information.

The committee of the American Chemical Society is composed of A. M. Buswell, *Chairman,* W. D. Collins and F. W. Mohlman. This committee has reported through its chairman, who is also chemical referee for the A. P. H. A., to Dr. Norton.

It has been the custom for these committees to revise *Standard Methods* at intervals of five years. The last revision occurred in 1925, and the revision for 1930 is now actively under way. In order to bring more forcibly to the attention of the various committees the needs and opinions of prominent chemists in sewage work the Editor of THIS JOURNAL sent out a request for short articles from eighteen chemists and engineers throughout the United States. The men were selected from geographical considerations as well as prominence in sewage work. The replies of fifteen who sent in contributions for publication follow. Two engineers did not feel qualified to discuss chemical methods. One chemist did not reply.

The Editor would be pleased to receive comments and discussion from other chemists and engineers throughout the country, who would like to contribute to this symposium. In view of the fact that this opportunity comes only once in five years it would appear that it is a privilege to contribute to this work.

The need for standard methods is recognized not only in this country but also in Europe. In 1929 the British Ministry of Health published "Methods of Chemical Analysis as Applied to Sewage and Sewage Effluents." (THIS JOURNAL, Vol. I, p. 577, Oct., 1929.) The Water Chemistry Group of the German Chemical Society is also engaged in the preparation of standard methods of water and sewage analysis. (THIS JOURNAL, Vol. II, p. 308, April, 1930.)

These foreign developments indicate the appreciation of the value of American standard methods. A list of the American chemists and engineers who have contributed to all past editions of *Standard Methods* would include most of the prominent names in the field of water and sewage chemistry and bacteriology. The committee which presented the first report in 1905 consisted of George W. Fuller, *Chairman*, G. C. Whipple, *Secretary*, H. W. Clark, Edwin O. Jordan, H. L. Russell, J. W. Ellms and R. S. Weston. Dr. Jordan is still carrying on the work of this committee. The following articles are presented for the consideration of this committee and all of those interested in the analysis of sewage and sludge.

Comments by Jack J. Hinman, Jr.*

Since the methods employed in the examination of sewage have been developed from the procedures first employed in the examination of waters, it is logical that the earlier editions of the manual on *Standard Methods of Water Analysis*, published by the American Public Health Association, should have considered the examination of sewage in a strictly secondary manner and included modifications of the methods when necessary rather than devote a special section to the manner of examining sewage and industrial waste. With the appearance of the fifth edition of the book in 1923, we find for the first time a special section, Part II, *Examination of Sewage, Effluents, Industrial Wastes and Grossly Polluted Waters*. There is also included Part III, *Examinations of Sewage Sludge and Muds*. In the sixth edition (1925), now published jointly by the American Public Health Association and the American Water Works Association, the same sections reappear, occupying the same amount of space.

The tremendously important changes in methods of disposal of wastes and the increase in the public insistence upon stream protection since the inauguration of the *Standard Methods of Water Analysis* have merited the special attention being given to the subject and really call for a much more detailed treatment of the particulars of the examination. It is the belief of the writer that quite complete directions should be given in *Standard Methods of Water Analysis* in order that newcomers to the field may be able to obtain satisfactory analytical results without necessarily consulting any other text. Those who wish to enquire more deeply into the special procedures should be provided with a fairly ample bibliography for each method. It is quite generally agreed that the purpose of the *Standard Methods of Water Analysis* is to supply the details of each determination without attempting to enter into a discussion of the meaning and inferences to be drawn from the values obtained. To do otherwise is to introduce serious confusion because of the many local variations in the information to be derived from the analytical work.

The members of Committee No. 1, of the American Water Works Association, which coöperates with the committee of the American Public Health Association, are in general more interested in the examination of drinking waters than of sewage and industrial wastes. However, in connection with the protection of the raw waters with which they have to deal, all of them must be more or less concerned about sewage examinations, and some devote most of their efforts to sewage work. The organization of the committee at the present time is as follows:

* *Associate Prof. of Sanitation, State Univ. of Iowa and Chief, Water Lab. Div., State Hygienic Labs. Chairman, Committee 1, Standard Methods of Water Analysis, Am. Water Wks. Association.*

Bacteriological Subdivision:
Mr. H. G. Dunham, Detroit, Michigan.
Mr. Norman J. Howard, Toronto, Ontario.
Mr. Harry E. Jordan, Indianapolis, Indiana.
Dr. Max Levine, Ames, Iowa.
Mr. MacHarvey McCrady, Montreal, Quebec.
Dr. John F. Norton, Detroit, Michigan.

Chemical Subdivision:
Mr. R. C. Bardwell, Richmond, Virginia.
Mr. John R. Baylis, Chicago, Illinois.
Dr. A. M. Buswell, Urbana, Illinois.
Mr. Dale L. Maffitt, Des Moines, Iowa.
Dr. F. W. Mohlman, Chicago, Illinois.

Microscopical Methods (Plankton):
Mr. W. F. Langelier, Berkeley, California.

Field Representatives:
Mr. Linn H. Enslow, New York, N. Y.
Dr. William U. Gallaher, Chicago, Illinois.
Mr. S. T. Powell, Baltimore, Maryland.

Committee Chairman:
Mr. Jack J. Hinman, Jr., Iowa City, Iowa.

In connection with the 7th Edition of the *Standard Methods for the Examination of Water and Sewage*, upon which work has been going on for some time, it is hoped that very definite progress may be made by the time of the meeting of the American Public Health Association during the month of October, 1931, and that the proposed material may be submitted to the American Public Health Association and the American Water Works Association for approval so that actual publication may be carried through in 1932.

With regard to the needed changes and extensions in those portions devoted to the methods for sewage and sludge analysis. The writer would suggest the following:

Sampling.—Accurate sampling of sewage and stream waters is much more difficult than sampling of ordinary water supplies and hence more apt to be incorrectly carried out. It is therefore desirable to enter rather fully into the discussion of the difficulties of securing representative samples and to give suggestions as to the manner of collection.

Preservation of Samples.—This subject of preservation of sewage samples needs elaboration. The highly decomposable nature of the material requires some preservative for certain parts of the work, but the preservatives interfere with the conduct of some of the tests. The use of alkalies is not mentioned in the current book.

Nitrites and Nitrates.—Some wastes are high in nitrites and these

interfere with the reduction test for nitrates. The manner of destroying the nitrites to prevent this error is described by G. W. Burke, Max Levine and G. H. Nelson (see below).

Biochemical Oxygen Demand.—This section needs considerable enlargement. Among the matters which require careful discussion are the method of dilution of strong wastes so as to avoid reaeration and inaccuracy of measurement, the so-called synthetic dilution waters, the calculation procedures and the recent direct methods for the determination such as those employed by Sierp and Theriault. There is little doubt that the nitrate method may be removed from the approved procedures without objection.

Suspended Solids.—More details about the use of Gooch crucibles and porous crucibles are desirable. It appears that some laboratories are using the Gooch crucible mats several times before discarding. The influence of the repeated heating on the organic matter in the filter should not be neglected. Porous crucibles may yield results which are sufficiently accurate for the purpose in mind. However, some mention of the means of removing material from the porous walls is desirable.

Settleable Solids.—This determination is so generally made that a standard procedure is urgently needed. As early as the 2nd Edition of *Standard Methods*, in 1912, mention was made of the cone used for this determination by Dr. Imhoff in Germany, and references were given to the methods which had been used in Great Britain. The references were so brief, however, as not to constitute a standard description and they were entirely removed from the material in the 5th and 6th Editions.

The Imhoff cone is now in very general use for determining settleable solids in sewage plants throughout the United States and Canada, but there is difference of opinion and practice with regard to the time of settling. Some tap the cone to loosen the sediment lodged on the walls of the vessel, and others follow more or less the rotation procedure laid down by Dr. Spillner for the use of his sedimentation glass, which seems to have been the predecessor of the Imhoff cone. Mention should also be made of the method by which grease from the sewage depositing on the glass walls may be removed in order to reduce the error of adherence to the walls by the sedimented matter.

It is also worth while considering whether the more delicate measurements of the Spillner sedimentation glass may not be more desirable in the work of plants controlled by complete laboratories, replacing the Imhoff cone for such places. ("Absetzgläser zur Kontrolle mechanischer Kläranlagen," Spillner, *Gesundheits Ingenieur*, **33,** pp. 721–724 (1910).)

Determination of the curves showing sedimentation rates may be worth mentioning also. ("Zur Bestimmung der Abwasserabsetzkrummen," H. Van der Zee, *Gesundheits Ingenieur*, **52,** pp. 243 and 246 (1929).)

Hydrogen Sulphide.—The determination of hydrogen sulphide as given in the sections devoted to water analysis is really a determination of the iodine-consuming power of the water or waste. Wastes containing iodine-consuming substances, such as thiosulphates and the like, will give false values for hydrogen sulphide. It is desirable to determine both the free hydrogen sulphide and that which is capable of being liberated from fixed or volatile sulphides. As a more definitely specific procedure, the antimony method recently developed in California merits special consideration, though perhaps further study is to be required before incorporating it in the recognized list of methods for the determination. See "Antimony Method for Sulphide Determination," by A. J. Salle and E. A. Reinke, *California Sewage Works Journal*, **2**, pp. 208–209 (1929).

Chlorine Demand.—In view of the extensive use of chlorine in sewage treatment to delay decomposition in long sewer lines, in odor prevention and in other treatment, the determination of chlorine demand of sewages should be made a special subject. This naturally involves the determination of free chlorine after treatment.

Phenols.—Studies of phenols in raw waters have been carried out extensively. There is, however, a need for simple procedures for determination of phenols when present in relatively large amounts as in the wastes from gas works. These are probably sufficiently developed in the gas industry for the purposes of sewage examination, but the matter needs investigation and the procedure recommended should appear in the book of standard methods.

Other Substances.—There are a number of other substances which occasionally require determination in wastes and which are in need of special study for their analytical determination under such circumstances. Among these are the cyanides, the sulphites and other materials used in industrial processes. The determination of crude fibre as practised in the analysis of foods and feeding stuffs may occasionally be useful. The importance of sulphates as sources of the sulphides following bacterial reduction should not be forgotten and while they may be treated adequately in the sections on water analysis, some mention should be made of the sulphates in the sections on sewage examination.

Comments by Stuart E. Coburn*

XXVI—2.—The time of sampling of one hour or possibly one-half hour is not often enough for sewage and especially industrial wastes when a test run of only a day or two is made. In such cases the time should be reduced to 10 or 15 minutes. With effluents or on routine collection

* *Chief Chemist, Metcalf and Eddy, Statler Bldg., Boston, Mass.*

of samples of wastes, the time given is satisfactory. The statement that the proper volume for the composite samples "should not exceed 4 liters" would be better if the statement were "should not be less than 4 liters."

XXXVI—2.—The use of a water-bath with sample bottles submerged should be included as an alternative to the water seals. The method of keeping the samples in a water-bath is easier to use and as accurate as the water seals and will do away with the 20° incubators where the tap water is approximately this temperature.

XXXVII.—The question of diluting water for use in biochemical oxygen demand determinations should be settled. For comparisons of sewages and effluents in different places it is advisable to use aerated mineralized distilled water. For studying the effect of a sewage or effluent on a given stream it is preferable to use the stream water as a diluent.

Miscellaneous.—Alkalinity, acidity and pH determinations should be included in a revision of this chapter.

Part III.—Under this heading, methods of analysis of scums, skimmings and grit chamber material should be included.

Comments by A. J. Fischer*

In view of the contemplated revision of *Standard Methods*, the following comments on these methods as applied to the analysis of sewage, sludge and grit appear to the writer to be appropriate at this time:

pH Value.[1]—The use of the color chart and the drop-ratio method should be discarded in favor of the use of the double-tube comparator method using either buffer solutions or colored glass as standards. Sludge, because of its high buffer content, can be diluted as much as twenty times with distilled water without changing the pH value so as to cut down the turbidity which would otherwise obscure the color. Stronger dye solutions than those recommended by Clark and Lubs should be used because of absorption of dye by the colloidal matter in the sewage or sludge. Care should be taken to obviate excessive aeration, otherwise high results will be obtained due to the liberation of carbon dioxide.

Ammonia Nitrogen.—Direct nesslerization appears to be more desirable than distillation. High results are apt to be obtained by the latter method because of the decomposition of nitrogenous material in heating. The writer has found that the addition of 1 cc. each of 10 per cent sodium hydroxide and 10 per cent copper sulphate in the order named to 100 cc. of sample always gave a clear color on nesslerization.

Nitrite Nitrogen.[2]—The use of dimethyl-alpha-naphthylamine has been reported by some analysts as being preferable to alpha-naphthylamine because the former gives a more permanent and distinct color.

* *Research Engineer, Dorr Company, 247 Park Ave., New York, N. Y.*

It might be pointed out that 1 cc. of the standard sodium nitrite solution as given in *Standard Methods* contains 0.00005 mg. nitrogen and not 0.0005 mg. as given.

Nitrate Nitrogen.—In the reduction method of determining nitrates, it should be stated that nitrites are included and should be subtracted from the results.

Settleable Solids.—This determination might well be included in the sewage section of *Standard Methods*. It is well recognized that the removal of suspended solids by a settling tank does not represent its true efficiency, as a large part of the suspended material in raw sewage will remain in suspension even on quiescient settling for a long period. A much better index of settling efficiency may be obtained by the method suggested by C. C. Hommon, in which a sample of raw sewage is settled in an Imhoff cone or a tall cylinder for two hours, after which part of the supernatant is siphoned off and analyzed for suspended solids. This, in conjunction with the suspended solid determination in the raw sewage and in the tank effluent gives the true efficiency. This is, in effect, a gravimetric determination of settleable solids.

Oxygen Consumed.[3]—This determination, although rapidly falling into disuse in ordinary routine sewage analysis, may be valuable in the determination of putrescible organic matter in grit. The method of G. W. Burke has been used in this connection with good results. This method comprises addition of 25 cc. of standard potassium permanganate to various amounts of sewage in Erlenmeyer flasks. After adding 10 cc. sulphuric acid, the contents of each flask were all diluted to the same volume. After digesting for thirty minutes each sample was titrated, using oxalic acid to decolorize the excess permanganate before titration. Comparisons were made on the basis of the oxygen-consumed values, obtained where the permanganate reduction was 60 per cent.

Biochemical Oxygen Demand.—There is more need for standardization of this determination than any other, due to the enormous amount of work carried out on it during the past five years. No two persons seem to agree as to the correct procedure, especially in regard to the type of diluting water that should be used.

The writer has secured excellent results using aerated distilled water to which 250 p. p. m. sodium bicarbonate has been added. Dilutions were made so that the dissolved oxygen content of the diluted sample did not fall below 1 p. p. m. after 5 days incubation at 20° C. Incubation was carried out in 250-cc. glass-stoppered bottles completely submerged in a water-bath. No incubator was used. The water in the bath did not vary more than ±2° F. Errors most likely to occur are due to the use of bottles not cleaned with chromic acid, to diluting water not stored for a sufficient length of time and to a thiosulphate solution that weakens on

standing. The latter should be checked up frequently especially after it is freshly prepared.

Putrescible Matter in Grit.—The efficiency of a grit chamber is usually determined by the volatile matter content of the grit. This is obviously incorrect as such material as coal, seeds, etc., contribute a large part of the volatile water and are non-putrescible.

In order to determine how much of the volatile matter was putrescible, tests were run on grit samples obtained from a number of plants. The method finally adopted was as follows: 100 grams of drained sample were introduced into a 2-qt. Dazey churn and 1100 cc. of clear water added. After rotating the churn at 120 r. p. m. for one minute, the stirring paddle was removed and the contents of the jar gently stirred to cause the seeds and other floating material to settle out. After 30 seconds settling, 1000 cc. of supernatant were decanted or syphoned off. Four more washings of the remaining grit were then made, using 1000 cc. of fresh water each time. The use of 500 cc. of wash water may be satisfactory for grit low in putrescible matter. The supernatant liquors were composited, evaporated to dryness, weighed and ignited to drive off all the volatile matter. The loss in weight after ignition, represented the putrescible solids in 100 gm. of wet grit. This was then reduced to a dry basis by determining the weight of solids left in the jar.

$$\% \text{ putrescible solids} = \frac{\text{Wt. of dry solids in washings} \times \% \text{ loss on ignition}}{\text{Wt. of dry solids in washings} + \text{wt. of dry solids left in jar}}.$$

The results obtained were checked up chemically by determining the oxygen consumed and biochemical oxygen demand (dilution method) of the individual supernatant samples. Solids, ash, oxygen consumed and biochemical oxygen demands (nitrate method) were also run on the original grit and on the grit remaining in the jar after washing.

Typical results obtained on samples of grit from Salem, O., were: Method: Grit drained for 1 hour on $^1/_{16}''$ mesh wire. One hundred grams wet grit placed in churn with 1100 cc. distilled water. Procedure as outlined above.

Results	Total Solids, Grams	Volatile Matter, Grams	Total Oxygen Consumed, Mg. O	B. O. D. 1 Day @ 20° C. Total Mg. O
1st supernatant	3.220	1.620	812	900
2nd supernatant	0.900	0.400	127	168
3rd supernatant	0.435	0.186	64	50
4th supernatant	0.295	0.120	22	24
Total supernatant	4.850	2.326	1025	1142
Grit at end	57.780	7.080	199	....
Total	62.630	9.406	1224	....

$$\text{Total \% volatile matter} = \frac{9{,}406}{62{,}630} = 15.00$$

$$\text{Total \% putrescible matter} = \frac{2{,}326}{62{,}630} = 3.71.$$

Other similar tests gave:

Test No.	1	2	3	4	5	6	7	8	9
% volatile matter	11.88	20.50	18.83	14.00	14.60	8.18	9.72	45.30	46.30
% putrescible matter	3.60	3.32	4.31	3.75	4.00	3.08	4.20	4.21	3.07

All of the above analyses were made on samples of grit from the Salem, Ohio, plant.

Material from other plants gave the following:

Plant	Aurora, Ill.			High Point N. C.	Winston-Salem, N. C.			
% volatile matter	49.8	25.83	34.83	14.50	11.0	23.5	40.2	8.0
% putrescible matter	3.30	4.63	2.03	1.80	0.9	2.20	1.9	0.8

References

[1] A. J. Fischer, "Determination of the pH Value of Sewage Sludge." *Proc. New Jersey Sewage Work Assn.*, **1928.**

[2] F. G. Germuth, "Dimethyl-Alpha-Naphthylamine for Determination of Nitrite Ion," *Ind. Eng. Chem.*, Anal. Ed., **1**, 28–29 (1929).

[3] G. W. Burke, "The Oxygen Consumed Determination," *J. Am. Water Wks. Assoc.*, **20**, 677–83 (1928).

Comments by Linn H. Enslow*

I have just one thing to suggest without going into the matter more carefully and that is the need of a reliable method for hydrogen sulphide determination. There is a standard method for its estimation in water but even so the iodine demand of many waters cannot be considered as truly indicating the hydrogen sulphide content.

Salle and Reinke of the California State Department of Health have developed a method for sulphide estimation by the colorimetric route. Antimony tartrate is the reagent employed to produce from the sulphide sulphur the yellow color of antimony sulphide. It has appeared in the *Calif. Sewage Works Jour.*, **II**, 1, 208 (1929).

Elder and Buswell have suggested the use of methylene blue production (Almy method) as a method for colorimetrically estimating the total sulphide sulphur. The reagents employed are *p*-amidodimethylanilin hydrochloride and ferric chloride. In the presence of hydrogen sulphide methylene blue is produced and the color compared with standards. (*Ind. Eng. Chem.*, **21**, 260 (June, 1929).)

Either of these methods could be perfected to indicate the total and the volatile hydrogen sulphide by a double determination—one being on an aerated portion and another on the non-aerated—the difference being volatile sulphides.

In lieu of a satisfactory method for evaluating the results of odor control by means of sewage chlorination, by measuring reduction of hydrogen sulphide in the sewage, we have used the attached method which is an

* *Sanitary Engineer, The Chlorine Institute, 30 E. 42nd St., New York, N. Y.*

adaptation of the existing standard methods for water analysis. The difference in iodine consumed by the aerated and non-aerated sewage sample is assumed to be that required by volatile hydrogen sulphide; the difference between the titration of aerated acidified and non-acidified portions is assumed to be the non-volatile sulphide iodine requirement.

None of these methods may prove to be the most satisfactory, and some study is badly needed to develop a method which will prove practical and fairly accurate for use in field tests along sewers and streams.

I have not had much experience with the colorimetric method of Salle and Reinke but if sufficiently sensitive it has the merit of being very simple. My single experience with the method led me to believe that differences of 0.5 p. p. m. hydrogen sulphide were about the smallest that could be estimated.

In addition to the need of a method for hydrogen sulphide estimation I think the test for residual chlorine should be standardized for sewage and effluents. The proportion of ortho-tolidin reagent as recommended for water is not applicable to sewage and in several other directions modifications of technic for sewage testing are desirable. The standards compounded for water are not applicable to sewage testing.

I would like to recommend brilliant green bile broth as a standard method for determining the *B. coli* content of sewage. This medium might well be employed as the single enrichment medium and positive gas production considered as partially confirmed *B. coli*, with eosin methylene blue plate reading taken as the final confirmation without further work except that transplanting the secondary brilliant green bile broth might be optional.

My experience has been that a greater *B. coli* index for sewage effluents has been obtained from brilliant green bile tubes than from the standard broth. This brillant green bile broth containing 2 per cent bile and 1:75,000 brilliant green has been recommended by the A. W. W. A. Committee No. 1 on Standard Methods for incorporation in the A. P. H. A. methods for water analysis. For sewage work the original Hale media containing 5 per cent bile and 1:10,000 brilliant green might be even more practical and satisfactory—for whatever *B. coli* inhibition might result would prove of minor importance in sewage and polluted stream testing, as compared with the elimination of overgrowths by anaerobes. In this instance gas production during the first 48 hours could be recorded as *B. coli* positive with subsequent plating on eosin methylene blue optional.

Comments by W. Rudolfs* and H. Heukelekian**

It is assumed that no great changes in the style and purpose of the

* *Chief, Dept. Sewage Disposal, N. J. Agric. Expt. Station, New Brunswick, N. J.*
** *Research Bacteriologist, Dept. Sewage Disposal.*

methods will be made, but we are wondering whether the time is not ripe to devote more attention to special methods concerning industrial wastes, possibly a separate section rather than including them with the analyses for sewage. There are a number of laboratories where industrial wastes are being studied more or less extensively and where certain methods are used which would help if they were brought together and published in a separate section. It is appreciated that each of the wastes is a problem by itself, but a beginning should be made with the important ones. It is a fact that in a number of cases the methods worked out for sewage analyses are inapplicable to industrial wastes and the sooner a beginning is made with the segregation and publication of specific methods for industrial wastes the quicker industrial waste research and solutions of the problems will result.

Biochemical Oxygen Demand.—It is fairly well evident that some other water besides distilled or tap water should be selected for dilution water in the determination of B. O. D. However, we believe it would be a mistake at present to decide to use any definite water containing single salts or combination of salts. Experimental work conducted in our laboratory has forced us to the opinion that any of the proposed salts to be used in the diluting water are highly arbitrary. Instead of deciding on a definite dilution water it would be far better if more data were collected in different competent laboratories before a final decision is made. The use of single salts like $NaHCO_3$ or KH_2PO_4 or $KHCO_3$ is undoubtedly better than distilled or tap water without any of these salts. It would seem to us that a more complex synthetic water simulating the important ions in the stream in the district both in respect to quality and quantity as far as possible would be less artificial and more balanced. If we are correct the ideal dilution water would be the one that would give a good comparison with the stream under observation or the water of the district.

In connection with the present method or any method proposed in which dilution is used it would be well to include in the published methods an approved procedure in calculating and selecting the results from the different dilutions of the sample. There should be uniform practice, either using the average of all dilutions, selecting the one that comes nearest to 50 per cent depletion, or calculating according to Theriault's difference method.

Dissolved Oxygen.—It should be definitely stated that when the first 1-cc. portion of permanganate disappears and subsequent additions become necessary, either 20 minutes should elapse between the first and final addition or 20 minutes between the next to the last and the last addition.

When the precipitate is formed on the addition of manganous sulphate

and potassium iodide it seems to be quite essential to allow the precipitate to settle completely before proceeding. If the precipitate does not settle after the first shaking it frequently settles if the bottle is shaken again. It also happens sometimes, due to some error in addition of the reagents, that the solution is not alkaline enough, causing the precipitate to disperse and the liquid to become brown rather than colorless. In such cases the addition of a little alkaline iodide corrects the trouble.

Hydrogen-ion Concentration.—The method for determining pH values in water cannot be applied to the determinations of pH values in sludge samples and sometimes not in the determination of pH values in crude sewages. In view of the emphasis placed upon pH control in sludge digestion in different parts of the country it might be well to include an adaptation of pH determinations to sludge samples. The most important step in this connection is the clarification of the sample. The greater the turbidity of the solution the greater the color absorption will be. Various pH values can be obtained from the same sample by varying the turbidity of the liquid. Filtration as a means of clarification either with or without suction is not satisfactory. Filtering media such as filter paper or glass wool have been used, also good clarification can often be obtained with a high-power centrifuge. The method of diluting sludge to certain limits is satisfactory, provided the concentration of the indicator dye solution is increased in order to counteract the adsorption effect of the turbid material.

Oxygen Consumed.—It is our opinion that the percentage of permanganate consumed should be exactly specified. The suggestion made by Burke (*J. Am. Water Wks. Assoc.*, **20,** 677–683 (1928)) to take a quantity of the sample that will reduce approximately 15 cc. of the $KMnO_4$ or 60 per cent, is shown to be of value, because if the reduction is greater or less the results will be variable.

Ammonia.—Several precautions should be taken in making standard solutions in the preparation of ammonia-free water. We find that the following precautions are necessary in making standard solutions.

(*a*) Rinse pipette with a small portion of ammonium chloride.
(*b*) Wipe pipette on the outside of the Nessler tube to remove adhering drops.
(*c*) Touch the last drop off on the inside of the Nessler tube.
(*d*) Discard ammonium chloride solution if it begins to take a cloudy appearance.

For preparation of ammonia-free water use a copper still. For each liter of water add 2 gms. of $KMnO_4$ and 20 gms. of NaOH. Discard until no color develops on testing with Nessler's reagent.

Nitrates.—In the description of the reduction method it is stated that reduction by aluminum foil takes place within 4 hours. In a number

of raw sewages and effluents this is not the case and it has been our practice to allow 48 hours to elapse for complete reduction. Determinations made after 4 hours on the same sample might vary greatly, whereas the determinations made after 48 hours give close agreement.

Time required for distilling has been found to be of importance for good results and we boil off the original ammonia content by adding 2 cc. of alkali and boiling to half of the volume in 5 minutes.

Total Nitrogen.—In expressing the results of total nitrogen in sludges and muds it would be well to have uniformity by requiring the determinations to be made either on the dry or wet sample. We find that the practice varies in different laboratories.

Grease and Fats.—Our experience has shown that drying the ether extract at a temperature of 103° C. is too high and causes a loss of volatile extracts and gradual loss of weight. It is often impossible to obtain a constant weight even after a great number of weighings. We do not believe that it is necessary to dry the ether at such a high temperature and that good results can be obtained at, say, 60° C.

Hydrogen Sulphide.—No method of determining hydrogen sulphide in sewages and effluents has been given. The method of determining H_2S in water is not applicable to sewages. Iodine should not be added to sewage to react with H_2S since other substances in sewage will react with it. A better method of approach would be to liberate and sweep out the H_2S and bubble through a standard solution of iodine. In view of the emphasis laid on odor control this or a modification of such a method should be included in the standard methods.

Carbon.—In view of the fact that carbon content (total or organic) has an important bearing in conjunction with total nitrogen, on the biological transformation and since this fact is being taken cognizance of and carbon determinations are being made in greater numbers, we think it advisable to include an appropriate method for the determination of carbon in sewages and sludges.

Comments by Morris M. Cohn*

That social register of laboratory practice, *Standard Methods of Water Analysis*, will soon appear in its latest form and an anxious public will closely scan its pages to determine if its favorite procedures have been adjudged of sufficient merit to be included among those receiving the coveted official sanction. It remains to be seen if the tests for the examination of sewage, effluents, industrial wastes and grossly polluted waters and for the examination of sewage sludge and muds, enumerated in the 1925 issue, have withstood the rapid pace of progress that sewage treatment

* *Sanitary and Testing Engineer, Bureau of Sewage Disposal, Schenectady, N. Y.*

has experienced in the past five years and can "make the grade" and enter the bigger and better edition.

Seriously, the inclusion of a separate section on the examination of these liquids and of sludges and muds was a splendid move and should, by all means, be continued. There may be certain refinements in procedure, or additions or omissions of pertinent or unessential examinations, made from issue to issue, but the method of attack cannot expediently be improved. Written on the cook-book style, *Standard Methods* should be to the laboratory worker what a book of tested recipes is to a good cook. There is much need for uniformity in reporting the results of treatment works operation but there is still greater need for the standardization of the methods used for the determination of those results. While standardization might have a tendency to inhibit personal initiative, the progress of the science must rest upon the foundation of a true comparative review of operation results obtained by different types of treatment devices at widely-separated locations. *Standard Methods*, in standardizing the maze of multitudinous methods, is the piling that supports the foundation of which we speak.

To paraphrase a famous remark, "Examination without representation is falsity," an analysis is no better than the sample being examined. In the type of materials under consideration, there is every possibility of wide variations in sampling. The matter of obtaining a field sample that truly represents the entire body of liquor or sludge being examined is one wholly dependent on the keenness of the manipulator. The use of automatic samplers has been suggested and may some day be proved as highly desirable.

It might be pointed out, under the subject of sampling, that many laboratories carry out their routine studies on weekly composites of daily composite samples. This procedure is followed at Schenectady, 300 cc. of the unfiltered and a similar amount of filtered samples being composited daily to make up the week's representative samples. Sterilization is by formaldehyde and sulphuric acid, two complete sets of composites being provided to permit both types of sterilization being carried out. Filtration is carried out by means of Whatman No. 1 paper.

The procedures given in the 1925 edition of *Standard Methods* for the determination of the various forms of nitrogen, and for oxygen consumed, dissolved oxygen, relative stability, solids, grease, chlorides and iron are not particularly in need of revision.

There has been much discussion of late on the merits of the various methods of determining the biochemical oxygen demand of sewage effluents and industrial wastes. Unfortunately for the cause of standardization, there has been but little agreement between manipulators. The dilution method is open to many errors and in the hands of an inept analyst can

give most ridiculous results. It has been our experience at Schenectady that a change of personnel in the sewage-works laboratory brings about a complete change in the complexion of the B. O. D. removal efficiency of the treatment units and results in the inability to compare present results with past performance. The various concentrations give different results that are only explainable by the influence of mass action. The use of seals has proved to be of no distinct value at Schenectady. The use of the Sierp apparatus for biochemical oxygen demand studies offers a more rapid and more flexible method for the determination of this valuable information; there is need for more extended work with this equipment before it can be used for standard practice with any measure of security. It is unfortunate that the omission of this method of determination from *Standard Methods* will prevent its adoption as routine for the next five years. A complete study of available Sierp data might be in order at this time.

The determination of the hydrogen-ion concentration of sewage, effluents, industrial wastes and polluted waters is simple and offers a valuable index of the character of the liquids. A standard method for the determination of the pH has been included in *Standard Methods*. At Schenectady excellent results have been obtained by means of a LaMotte 3B cell set. The small cells require but a few drops of the sample and color comparisons have not been hampered by the turbidity of sewage or effluent samples.

The test for residual chlorine with ortho-tolidin indicator should be repeated under the sewage section, with procedure for neutralizing the effect of the turbidity of the liquid.

Methods for the examination of sludge and muds have advanced but little in the past five years. The procedures given in the 1925 *Standard Methods* for the determination of reaction, specific gravity, moisture, volatile and fixed matter, organic nitrogen and fats are still representative of the best technique.

There is need for the inclusion of a procedure for the determination of the pH of sludge, scum and digestion-tank liquor. Methods for obtaining sufficient clarified sample for the tests, amount of dilution that the buffer action of sludge permits and approved procedure for the test should be included. With the awakening interest in reaction control of sludges, much new thought has been given to the subject of hydrogen-ion determination.

There appears to be a tendency to place some dependence on the biochemical oxygen demand of sludges as a measure of their condition. A standard procedure for this test on sludge might be included in *Standard Methods*.

There is a distinct necessity for a reduction in the amount of routine tests that are burdening the laboratory forces. Many of the determina-

tions being carried out at sewage laboratories are nonessential in the light of present-day knowledge. It is unfortunate but true, that the routine tests, on the unending stream of sewage samples that enter the laboratory, leave but little time for research thought on the part of the analysts. The catch samples or the various composites become a nightmare to many laboratory forces, while entrancing original problems are crying for solution. Fewer determinations, carried out with more uniformity, is what is most needed. *Standard Methods* can provide the latter condition. It remains for the national association committees to cut much of the dead wood from the laboratory programs.

Comments by T. C. Schaetzle*

The sewage and sludge sections of the 1925 edition of *Standard Methods* has been found generally satisfactory, but if this publication is to be considered a standard methods outline the writer feels that alternate procedures should be given only as a convenience to the users of the text and that a specific method should be given as *the* standard recommended by the committee responsible for this publication. For example, analysts differ as to the proper method for the determination of suspended solids. The present edition seems to indicate that the Gooch crucible method is to be preferred but that the difference method is also standard. Additional alternate methods are not advocated by the writer, but where they are given they should be so marked as to enable each user of the text to state whether or not he follows the exact adopted standard or the alternate.

Under Section 2 on "Collection of Samples," a definite statement of the time covered by a standard sample should be given and not a possible variation of 12 hours. To care for the smaller sewage plants with daytime attendance only, samples should cover an 8-hour period and at all plants with 24-hour supervision the period covered should be not less than 24 hours.

It is believed further that a definite preservative should be recommended by the committee as well as how soon the preservative must be added after sampling, if it is impossible to analyze promptly. These and many other items have been and will continue to be a source of difference between analysts, but "standard methods" should be what the name implies.

In the clarification of a sample of sewage or industrial waste for ammonia nitrogen by direct nesslerization, I have found it convenient to test the reaction after adding the copper sulphate and hydroxide. A test plate with about 12 depressions is convenient. Using 2 drops of phenolphthalein and 5 or 6 drops of sample, a light red color usually gives the proper re-

* *Engineering Chemist, Akron, Ohio, Sewage Treatment Plants.*

action for good sedimentation and clear Nessler tubes. To hasten the operation, filtration through a good grade of filter paper was used occasionally, with no apparent effect on the results.

In the phenoldisulphonic acid method for nitrate nitrogen determination I have found it convenient and satisfactory to eliminate the removal of chlorides when less than 200 p. p. m., but I have compensated for the color change due to the chlorides by adding an equivalent amount of chlorides to the standards. This procedure has been applied to routine sewage plant operation where the chloride content remains practically constant.

The collection of stream or tank samples need not, in my opinion, be taken as outlined on page 60. The immersion of the tightly stoppered bottle to the desired depth in, or attached to, a container provided with a compartment for a sample, from which the temperature can be obtained, and the removal of the stopper at this depth by a cord, or otherwise, seems sufficiently accurate for all practical purposes.

The writer prefers a 250-cc. bottle for relative stabilities with a correspondingly larger quantity of methylene blue solution. It is believed that 10 days incubation at 20° C. should be adopted as standard.

Perhaps the most difficult determination to standardize is the biochemical oxygen demand. Much could be written, but a few pertinent remarks appear sufficient for this discussion. In the writer's opinion, two distinct diluting waters should be used for sewages. To compare data between plants distilled water, whether adjusted or not, should be used; whereas the true measure of what the effluent of any individual plant or part thereof is doing or will do can only be determined by using the water from the receiving stream for dilution. For comparison between plants, however, some definite form of distilled water should be adopted.

It is suggested that the section on seals, p. 78, read, "To prevent loss of oxygen or reaeration during incubation, a water seal shall be used." Further, Par. 3 under "Procedure" might be modified to read..... filling the bottle to overflowing before inserting the stopper," to conform with the above suggestion.

If we are to standardize, here again the committee should go on record as recommending some definite incubation period, even though we know the demand is different for different incubation periods.

For "total residue," page 25, the drying temperature should be 103° C. to conform with Section 38. Likewise, the temperature in the last line under "procedure," in Section 14, should be 103° C. to conform with Section 39.

For volatile solids a definite temperature should be given. It is suggested that this be 600° C.

To prevent drawing holes through the asbestos mats when using the

Gooch crucibles I have found it advisable to apply the suction so that the filtrate comes from the crucible in distinct drops and not as a stream.

Being a firm believer that the true efficiency of any settling unit is shown by the removal of those solids which are capable of removal, I advocate a section on settling solids with the settling period equal to the theoretical detention period obtained from the average flow for the interval represented by the sample being analyzed.

In the sewage section no reference is made to alkalinity and pH determinations. I believe this should be done at least in the same manner as has been done for "Iron" on page 81. As pH plays a considerable part in sludge conditioning and industrial waste clarification problems, I would suggest an outline of the procedure for preparing samples up to the point of actual colorimetric comparison, at which stage reference can be made to the water section.

The analysis of sludge and mud samples needs little comment. Reference has just been made to a pH section under sewage. As comparatively few plants or laboratories have potentiometers it appears to me that the colorimetric determination should be adopted as standard.

As in the case of volatile sewage solids it would seem advisable to adopt a definite ignition temperature for sludge.

For the nitrogen content of sludge my experience indicates that the range in quantities of dried sludge used should be from 0.5 to 2.0 g. instead of 0.5 to 1.0 g. I believe distillation into acid is best for sludge, and inasmuch as it is an official method of the Association of Official Agricultural Chemists, why should it not be standard for the fertilizer value of sludge? Since sludge marketing has increased in recent years I should like to see the agricultural chemists' procedures for potash and phosphoric acid incorporated under the sludge and mud section of *Standard Methods of Water Analysis*.

Comments by Emery J. Theriault*

The following comment is offered regarding the proposed revision of Part II in the 1925 Edition of *Standard Methods*, with particular reference to Part II, pp. 69–85, dealing with the examination of sewage effluents, industrial wastes and grossly polluted waters.

(*A*) What is the correct way of referring to *Standard Methods?* Is the correct title *Standard Methods of Water Analysis*, as indicated on the outside cover, or should the publication be given the longer and more descriptive title of *Standard Methods for the Examination of Water and Sewage?*

(*B*) The separation of methods for the analysis of water and sewage into distinct sections appears unnecessary as it leads to considerable

* *Chemist, U. S. Public Health Service, 3rd & Kilgour Sts., Cincinnati, O.*

repetition and to some inconsistencies. For instance, the topic, "5. Preservation of Samples," is discussed at some length in Part II, pp. 69–70, with the recommendation that the samples be analyzed as soon as possible after collection. In Part I, p. 3, the preservation of samples is discussed under the heading "3. Time Interval between Collection and Analysis." The same general criticism applies to other topics where the main difference in procedure lies merely in the quantity of material taken for analysis or in the degree of pollution.

(*C*) Under "4. Preservation of Samples," p. 70, it is very doubtful whether "Sulphuric acid, when so added as to produce an acidity of 1000 p. p. m. appears to preserve the original equilibrium between the various forms of nitrogen." This does not seem to be the case with nitrites (Public Health Bulletin, No. 171, "A Study of the Pollution and Natural Purification of the Illinois River;" Appendix B, pp. 202–208, "Preservation of Samples for Sanitary Chemical Analysis.").

(*D*) Under "XXXV. Dissolved Oxygen," p. 74, it is perhaps unnecessary to use the permanganate modification in the absence of nitrites or iron salts. In the presence of much organic matter, lower results may be obtained with this modification than with the regular Winkler procedure (Public Health Bulletin, No. 151; "The Determination of Dissolved Oxygen by the Winkler Method," pp. 26–29; see also Public Health Reports, **44,** 11–12 (1929).) The subject will be discussed at length in a forthcoming article entitled "Detailed Instructions for the Determination of Dissolved Oxygen by the Winkler Method."

In the application of the permanganate treatment, a period of standing of 20 minutes is recommended. This period of standing is probably based on the time required for the complete oxidation of nitrites. For most practical purposes a five-minute detention period appears sufficient.

There is need for a revision of methods or, at least, a more careful statement of the technique in dealing with ferruginous wastes (mine drainage, for instance). The fluoride modification discussed at length in Public Health Bulletin, No. 151, appears very satisfactory.

The addition of oxalate for the removal of permanganate may lead to a considerable error if an undue excess is used (Public Health Bulletin, No. 151, pp. 20–26).

(*E*) In recent experiments with sulphite waste liquor it has appeared certain that the permanganate modification is altogether untrustworthy. The error when the waste is present in dilution of 1:600 may amount to 5 parts per million. The difficulty appears to arise from the decomposition of polythionates following the addition of the alkaline-iodide mixture. A practical degree of accuracy may be obtained with such wastes by a preliminary treatment with chlorine or hypochlorites, the excess of oxidant being removed by iodine and sulphites.

(*F*) In applying the relative stability test to sewage effluents, it should be borne in mind that, in theory, the test assumes an unvarying rate of deoxygenation. This condition may not be fulfilled with partly nitrified effluents. The possibility of empirical calibration of the test against observed conditions should, of course, be considered.

(*G*) The biochemical oxygen demand test has been discussed by the writer in Public Health Bulletin, No. 173, "The Oxygen Demand of Polluted Waters." A revision of the technique recommended in that bulletin will be embodied in a forthcoming article on "Detailed Instructions for the Determination of Biochemical Oxygen Demand by the Excess-Oxygen (Dilution) Method." The main departure from previous recommendations is the substitution of a buffered solution for tap water in cases where a suitable dilution water cannot be obtained. The present stipulations in *Standard Methods*, p. 77, regarding the properties of the dilution water are inadequate, as no provision is made for the presence of mineral salts. No mention is made, moreover, of the oxygen demand of the dilution water itself and of the necessary absence of bactericidal substances (chlorine compounds, for instance). Within certain limits it also appears advisable to specify the pH value of the dilution water.

The effect of variations in the nature, amount and pH value of various synthetic dilution waters has been studied extensively in the Stream Pollution Laboratory of the United States Public Health Service during the past year. A report on this study is being prepared and should be available to committee members and other interested workers prior to the revision of this section of *Standard Methods*.

Comments by Chas. C. Hommon*

It is believed by the writer that perhaps it would be well to define the terms "Suspended Matter" and "Settleable Solids" in *Standard Methods of Water Analysis* and give a method of determining each.

This thought is expressed because of the fact that the efficiency of sedimentation tanks employed in sewage treatment is dependent upon the ability of the solids contained in the sewage to settle; it is recognized by all that the more finely divided solids will not settle, therefore they are not capable of being removed by sedimentation. It is believed that many workers are employing the Gooch crucible method of determining the suspended matter content in the raw sewage and tank effluent for the purpose of figuring tank efficiencies. This is in error for the reason that the crucible method removes a percentage of material which plain sedimentation cannot hope to accomplish.

Knowing that sewages vary greatly in the amount of non-settleable matter carried in suspension it seems that it would be advisable to estab-

* *Department of Public Service, Canton, Ohio.*

lish a definite procedure for determining the quantity of settleable and non-settleable solids. The Imhoff cone is in common use for this purpose but it is a volumetric determination and subject to many criticisms.

In the control of the Canton, Ohio, Sewage Works, the amount of settleable solids and tank efficiency are determined by use of the Gooch crucible method in the following manner: The crucibles are prepared as set forth in the *Standard Methods of Water Analysis* and the suspended matter content of the raw sewage and tank effluent is determined on weighted daily composite samples. The amount of suspended matter is also determined in the supernatant liquid of the Imhoff cone after settling three hours, the theoretical retention period provided for in the settling tanks. A typical analysis will serve to illustrate the method and results.

The suspended matter contained in the raw sewage, tank effluent and supernatant liquid in the Imhoff cone after settling three hours, as determined by the Gooch crucible, was as follows—187, 69 and 57 p. p. m., respectively.

It is believed that it is fair to assume that if a settling tank is designed for a retention period of three hours, and a represenative sample of the sewage is allowed to settle three hours under ideal conditions, the amount of settleable solids removed under such conditions should represent practically 100 per cent of the matter capable of being removed by sedimentation. If this be true, using the above figures it follows that 130 p. p. m., which is the difference between 187 and 57 p. p. m., represents the total amount of suspended matter that it is possible to remove in the sedimentation process. Since the tank effluent contained 69 p. p. m. it follows that the tank efficiency may be said to be 91 per cent instead of 63 per cent if calculated in the usual manner.

This scheme of analysis is thought to be more nearly correct and of greater help, not only in the control of sewage works but in securing accurate data for design purposes.

Comments by C. K. Calvert*

All references are to the 1925 edition of *Standard Methods of Water Analysis*.

On page 70, Article XXVII, mention is made of the determination of turbidity and color. In sewage plant effluents appearance is of importance on account of its effect on the public mind. Particularly in an activated sludge plant, the effluent may have a turbidity of almost twice the actual weight of suspended solids. It would seem quite worthwhile to have information on the coefficient of fineness, which of course involves the determination of turbidity as well as suspended solids.

* *Chemist-in-Charge, Sewage Treatment Plant, Indianapolis, Ind.*

In fertilizer practice it is customary to use mercuric oxide instead of copper sulphate in a determination of total organic nitrogen. As time goes on, more and more plants will be interested in sludge for use as fertilizer. On this account it would seem desirable to standardize the nitrogen determination in sewage with that already established in the fertilizer industry.

On page 73, Section 3, 100 cc. or more of the sample is recommended for distillation into acid. It is quite unusual to encounter a sewage so strong in nitrogen as to make 100 cc. safe. It would appear that the standard amount should be increased or that the amount of sample should be so regulated as to make the weight of nitrogen fall within specified limits.

Relative Stability and Biochemical Oxygen Demand.—The relative stability method has been in disfavor by well-organized laboratories on account of the inaccuracy of the determination and the difficulty of obtaining comparable results. With better knowledge of the action of methylene blue of various compositions it would seem that it should be possible to obtain a dye of definite chemical composition which will insure comparable results from year to year on the same plant as well as between plants in different localities.

The whole question of biochemical oxygen demand, involving the type of bottle, method of sealing and composition of diluting water, is in such a muddle and affected by the opinions of so many different people that its value at this time is very much impaired.

The effect of the sewage on a stream, without the benefit of reaeration and sunlight, can be learned by diluting with stream water before the addition of the sewage in question. If necessary, blanks on this water might be run, seeding first with sewage organisms.

Considerable work has been done on the determination of B. O. D. by maintaining intimate contact between air and sewage samples under examination. This method is extremely cumbersome and expensive and cannot be used extensively by most laboratories.

In view of the above facts it would seem advisable to emphasize, particularly, the use of the relative stability method for plant control and of the aeration method for accurate check-up work, carrying on, at the same time, experimental work on the dilution method, anticipating the time when some standard method for this determination can be agreed upon. If the B. O. D. determination is kept in *Standard Methods* it would be well to insist on results being expressed as determined rather than factoring into other incubation periods. For the purpose of comparison between plants the five-day figure is probably preferable to the two-day figure.

It is perfectly obvious that the use of distilled water for dilution is wrong. Undoubtedly the ideal water is that obtained from natural sources, low in

organic matter and with a mineral content very near that of the sewage under examination.

Dilution Water for Bacteriological Examination.—Distilled water has been used almost universally for dilution of sample before plating. Undoubtedly this treatment of the organisms results in somewhat lower counts. An enormous amount of work would be required to determine the composition of diluting medium which will not affect the organisms to be considered. Many of them could best be suspended in physiological salt solution. Conditions might find such treatment too severe. Sterilized tap water has been suggested for this purpose. Such a medium in the Central West would have lost its bicarbonates and contain such a small amount of mineral salts that it would be very little different from distilled water. It would seem that, until more work is done on this subject, sterilized tap water should not be made standard.

With the increased use of gas from digested sludge some mention might be made of the analysis of the gas and certainly of the pH concentration of sewage and sludges.

Volatile Solids.—The determination of volatile solids on sewage residues or sludges in the Central West gives very erroneous figures on account of the CO_2 held in normal carbonates. Without correcting these figures on the basis of an analysis of the sludge ash, an expression of the extent of sludge digestion is distorted.

Comments by William D. Hatfield*

The following notes are the result of experiences in the routine analyses of sewage, effluents, sludges, river samples, and river bottom flora at the laboratories of the Sanitary District of Decatur. Only those analyses are discussed wherein a variation from *Standard Methods* (1925) is used or where additions of methods are indicated.

XXVI. Collection of Samples.—Our regular routine is to composite 24 hourly samples in gallon bottles which are kept cool in a cooling bath at from 12° to 16° C. The 24th sample is collected at 7 a. m. and at 8 a. m. Dissolved oxygen, B. O. D., nitrates, stabilities and suspended matter are determined. The daily sample is then composited into a weekly bottle and preserved so that average weekly determinations can be made of oxygen consumed, ammonia and total nitrogen. We have compared the three methods given in *Standard Methods* for preservation of samples and find that chloroform and chilling is the best method when all determinations are considered (except B. O. D.); 1000 p. p. m. sulphuric acid reduces the suspended matter, settleable solids, and oxygen consumed; and formaldehyde is not satisfactory for suspended matter,

* *Superintendent, Sewage Treatment Works, Sanitary District of Decatur, Decatur, Ill.*

oxygen consumed, and ammonia. We finally gave up using preserved samples for suspended matter and now run them on the daily sample. This was because of precipitation or solution due to time and the preservatives on the suspended matter.

XXIX. Ammonia Nitrogen.—In this determination ammonia-free water is necessary and in no place in *Standard Methods* is there a description of how this water can be made. There should be a description of the proper method of distilling ammonia-free water, also of the use of Folin's ammonia Permutit for making up small quantities of ammonia-free water.[1]

For the sake of convenience and economy in space and chemicals 5 × $^5/_8$-inch test tubes may replace the 120-cc. bottles recommended in *Standard Methods* and the quantity of copper sulphate and alkali added reduced to four drops each.

The distilled water at Decatur is almost always ammonia-free as used for direct Nesslerization, but it often gives cloudy tubes. The well water used is also ammonia-free. Cloudy tubes have been eliminated by using the well water after precipitation with copper sulfate and sodium hydroxide. The clear supernatant water should not be allowed to stand over the precipitate, but should be siphoned off. It is then stable and can be kept for a considerable time. We make up a gallon at a time.

XXXI. Organic Nitrogen.—The routine at Decatur and also at many other places is to determine total nitrogen and subtract from it the ammonia nitrogen if the organic nitrogen is desired. Should this method be included in *Standard Methods?*

XXXIII. Nitrate Nitrogen.—The reduction method is used, which includes also nitrite nitrogen. The usual water-seal trap has been found unnecessary since sanitary water and sewage laboratories do not ordinarily contain ammonia fumes. The sample is evaporated according to *Standard Methods* and poured into a 50-cc. Nessler tube or test tube graduated to 50 cc. The sample is then diluted to the 50-cc. mark, a loose-fitting glass stopper placed on top to exclude dust and the reduction and nesslerization made as usual. Sometimes it is difficult to get a clear sample for direct nesslerization. Our routine procedure is to pour off a test tube full of the reduced supernatant liquor (about 20 cc.) and add 4 drops of the copper sulphate solution, shake, settle and nesslerize from 1 to 5 cc. of this clarified liquor.

XXXIV. Oxygen Consumed. ($KMnO_4$).—Although this determination has lost much of its prestige it is still a valuable indicator of the strength of the sewage and may be used to predict the probable 5-day B. O. D. on the first day. If the author was not short on laboratory assistants he would run this test daily so that he would have an immediate indication of the probable B. O. D.

Definite directions should be made for the dilution of the sewage sample to a standard volume, say 100 cc., with distilled water. Further, the oxygen consumption of a blank sample of the distilled water should be determined with each set of tests in exactly the same way as the samples are being run and this consumption deducted from the titration of the samples before the oxygen consumed is calculated.

The procedure at Decatur is to dilute from 5 to 10 cc. of the sewage (so that at least 5 cc. of the standard permanganate is left) to 100 cc. with distilled water, add the acid and permanganate and proceed according to *Standard Methods* except for the correction for the blank as mentioned above.

XXXV. Dissolved Oxygen.—The Rideal-Stewart modification is used only on effluents, and river samples containing nitrites. It is not used on the dilution bottles after 5 days incubation.

The stabilized starch indicator of Nichols[6] using 2.5 grams starch and 1.25 grams of salicylic acid per 1000 cc. is much better than that recommended in *Standard Methods*.

In river samples that are highly polluted and have been treated with the Rideal Stewart modification, it has been found that a faint color of iodine (say 0.3 p. p. m. oxygen) on acidification must be titrated at once or the iodine will disappear on standing a few hours.

XXXVI. Relative Stability.—A definite quality of methylene blue should be specified instead of "or commercial variety." I suggest a standardized quality stain as recommended by the Amer. Soc. of Bacteriologists.

XXXVII. Biochemical Oxygen Demand.—The greatest error in the B. O. D. determination is the quality of the dilution water. The best indication of a good quality of dilution water is that it gives check results when two or three different per cent dilutions are set up on the same sample. A toxic water will give increasing results with increasing dilutions and a water whose organic matter is not stabilized will give decreasing results with increasing dilutions.

A most crying need is for a standard dilution water so that each laboratory will use a water containing all the necessary ions for good bacterial growth and in the same ionic concentrations. This standard dilution water is necessary in order to compare results. At Decatur[4] distilled water gives results 40 per cent lower than 500 p. p. m. sodium bicarbonate water[5] and the plant well water gives results 40 per cent higher than the bicarbonate water. It is plain that distilled water should not be used. Greenfield, Elder and McMurray[3] have shown the effect mentioned above due to the presence of calcium, magnesium, sulphate and chloride ions.

The author has found that equally good results can be obtained by measuring samples directly into the incubation bottles after having

filled them half full of dilution water and then filling them just into the neck so that the stopper will displace only a very small amount of water. The sample can then be thoroughly shaken. In using this method all bottles and stoppers must be permanently numbered and the volume of the bottles with their corresponding stoppers calibrated by weighing them full of distilled water. The volume is then scratched on each bottle. This calibration takes some time but is worth the time spent because it so greatly simplifies the daily dilution technic.

Three-quarter inch rubber tubing has been found to make a more handy rubber collar water seal than rubber hose, which is much less flexible and does not fit so well.

Extensive tests have shown that rubber stoppers with glass tubes, as have been used in some places, should not be used because the rubber has an oxygen demand which make the results high. Because of the extent of their use these should be specifically condemned.

Imhoff Cone Test.—Because of its very general use and its practical value the Imhoff cone test should be included in *Standard Methods*. This test does not give data that can be used quantitatively like suspended matter and B. O. D. but it is of considerable value to the operator in his daily work.

pH of Sewage and Sludge Liquors.—A good colorimetric method should be given which allows for compensation of color and turbidity. There should also be a limitation of the allowable amount of dilution for sludges. Wherever possible we run pH on undiluted samples and resort to as little dilution as possible. Medalia's method should not be recommended because it is inaccurate and unscientifically developed.[2] If one wishes to make up his own color standards, a modification of Gillespie's[2] method without buffers which the author published[4] in 1923 is quite satisfactory and inexpensive. This method is used at Decatur and gives color standards which are usually stable 3 or more months.

Microscopical Examination (of Sludges, and River Bottom Flora, as Well as Reservoir Water).—There will probably be opposition in this suggestion, but I can see no reason why this section should not be expanded with six or eight pages of hand drawings of the microörganisms common to fresh and polluted waters as well as septic and activated sludges. Twenty-five such drawings could be placed on a page, each drawing having a reference number. In a paragraph on another page could be given the reference numbers, the names and the usual size of the organism in mus (μ). One page could be made up of the 25 most commonly found Diatomaceae; another, the 25 most common blue-green algea, Cyanophyceae; another, the 25 most common green algae, Chlorophyceae; another, 25 amoeboid protozoa; another, 25 flagellated protozoa; another, 25 ciliated protozoa; and possibly a seventh page including

Schizomycetes, Rotifera, Crustaceae and miscellaneous organisms. The numerical distribution in the classes above is meant only by way of suggestion and not that there should be equal distribution.

The selection of organisms should be carefully made so that they might be applicable both in water, sewage and river survey work. Such a selection should not be difficult for one acquainted with the fields mentioned. Similar pages or plates containing 25 or more organisms to the page, though not logically arranged, may be found on pages 5 to 8 in Dr. Julius Wilhelmi's "Kompendium der biologischen Beurteilung des Wassers." A small black and white drawing is much more satisfactory than the highly colored plates in one of our commonly used text books on this subject.

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Comments by F. W. Mohlman*

There should be a complete revision of methods of analysis of sewage and sludge in the 1930 edition of *Standard Methods of Water Analysis*. There have been rapid developments in methods of sewage treatment during the past five years, with increasing need for better and more precise methods for measuring the true accomplishments of treatment and disposal. The time-honored tests of water analysis, such as turbidity, albuminoid ammonia and oxygen consumed are giving way to more enlightening tests, such as those for suspended solids, organic plus ammonia nitrogen, and biochemical oxygen demand. The value of the B. O. D. test is now acclaimed by all chemists and engineers engaged in the treatment and disposal of sewage and industrial wastes. The technique of the test is discussed at all meetings of sewage works operators. We have had quite satisfactory results with the dilution method and believe that with careful technique it is possible to obtain satisfactory check results, certainly in clarified sewage. It is hardly to be expected that close checks

* *Director of Laboratories, The Sanitary District of Chicago, 845 So. Wabash Ave., Chicago, Ill.*

can be obtained on samples of raw sewage or industrial wastes containing large particles of suspended solids.

Biochemical Oxygen Demand.—The 1925 method should be completely re-written. It is now known that it is not correct to state that "the complete demand is usually satisfied in 20 days at 20° C." The first, or carbon-oxidation stage, is usually complete in less than 20 days at 20° C., and the 5-day result bears a fairly constant relation to the total first stage. Incubation for 5 days at 20° C. should be made standard with recommendation that additional results be obtained with incubation up to 20 days for special sewage work or studies of stream pollution.

The nitrate method might just as well be eliminated as its use has practically been abandoned.

The selection of dilution water is not easy. Distilled water was used until it was shown to give low results. Deep-well waters are rarely satisfactory. They usually contain iron or a large amount of bicarbonate held in solution by CO_2, and not in equilibrium with the air. If softened, the pH may be too high. Surface waters are not constant and vary in organic content and from the effects of chlorination. Few streams are so low in organic matter that storage, even for long periods, results in stabilization. Such waters will usually give discrepant results in various dilutions.

Because of this unsatisfactory situation the use of distilled water containing a buffer was started in our Sanitary District laboratories some five years ago. Sodium bicarbonate was selected as being most nearly like the salt content of natural waters. At first 500 p. p. m. was used, but for the past two years this has been reduced to 300 p. p. m. in order to lower the pH. In some cases, where the salt content of natural waters is low, this has been decreased to 100 p. p. m. The many studies and comparisons we have made of this water and others cannot even be summarized here, but we have concluded that we prefer this water to distilled water, tap water, or synthetic waters containing $KHCO_3$, KH_2PO_4, or permolybdate.

Three years ago we decided to try synthetic waters containing most of the salts found in natural waters. Calcium and magnesium bicarbonate are fundamentally representative of natural waters but we found that the preparation and use of definite amounts of these salts was quite unsatisfactory since $CaCO_3$ or $MgCO_3$ must be kept in solution under an atmosphere of CO_2, under pressure. We substituted $NaHCO_3$ for $Ca(HCO_3)_2$ and got our Mg as $MgSO_4$, and Ca as $CaCl_2$. We averaged the concentration and composition of surface waters of the U. S. as reported in U. S. G. S. Paper 135, rounding off to 100, 200, 300 and 100 p. p. m. total solids for the Atlantic Slope, St. Lawrence and Mississippi River Basins, Texas and Southern Pacific Slope and Middle and Northern Pacific

Slope, respectively. Selecting the most common salts, with $NaHCO_3$ in place of $Ca(HCO_3)_2$, we calculated the average composition to be 70 per cent Na_2CO_3 (added as $NaHCO_3$), 10 per cent $CaCl_2$, 10 per cent $CaSO_4$ and 10 per cent $MgSO_4$. We have used this water occasionally, but are not convinced that it has any particular merit over $NaHCO_3$ alone. If, however, a more complex synthetic water is desired, we believe this is the rational basis for selection of the composition of the water.

Adjustment of pH is probably of more importance than nature of salt content. We are able to adjust the initial pH of bicarbonate water within the necessary limits to correspond with the pH of natural waters, and this reaction remains constant in stoppered bottles, but the pH decreases during incubation of diluted samples, although not so much as the decrease in synthetic water containing 42 p. p. m. KH_2PO_4.

We would recommend the use of $NaHCO_3$ water, 100, 200 or 300 p. p. m., wherever satisfactory tap water cannot be obtained. Research on more complex synthetic waters, possibly with adjustment of pH, would appear to be the next logical step toward the adoption of a standard dilution water.

Rubber tubes, stoppers or seals should not be in contact with the diluted sample. We use rubber collars, slipped over the lip of the bottle. Glass-collar reservoirs, blown with the bottle, are good but expensive, also the water evaporates more rapidly than with rubber collars and must be replenished in less than 5 days. One of our laboratories has had excellent results with a water-bath for a 20° C. incubator, with submerged bottles. Formerly bottles were inverted in a trough filled with water and incubated in an air incubator.

Relative Stability.—There is considerable doubt as to whether the relative stability test rests upon a reliable scientific basis, in view of more recent studies of the oxygen requirements of effluents, particularly activated sludge. The test is in the class with volumetric tests for settleable solids—that is, suitable for operators who do not have laboratories, or where only the simplest tests can be made. We make stability tests at all of our plants, but our operators give little weight to the results either for purposes of control or for a record of operation. Our experience has indicated also that the method is very crude for accurate work on polluted streams. It is also unsuitable for sterilized or caustic effluents. It would be desirable, therefore, to indicate in *Standard Methods* the limitations of this test.

Settleable Solids.—The widespread use of the volumetric test for settleable solids, with results reported in cc. per liter after two hours' settling, warrants inclusion of this method, at least for small plants or treatment works not equipped with a complete laboratory. For larger plants, which include a laboratory, it is far preferable to determine the settleable solids by weight. A 2-hour period of settling should be used in

Imhoff cones, with determinations of suspended solids on the original sample and the supernatant liquor.

While this method gives more accurate and more valuable results than the volumetric method, a study of the results reported in *Bull.* 132, U. S. P. H. S., indicates that the efficiency of sedimentation, measured by comparing actual removal in tanks with removal in Imhoff cones, varies widely from day to day for a given plant, in fact, over such a wide range as to cast doubt upon the value of the test. Routine results averaged over a long period might be more consistent. If tests for settleable solids are to be included in *Standard Methods*, this procedure should be recommended, with reference to the volumetric test (cc. per liter) for use only at small plants which have no facilities for complete analysis. Consideration should also be given to the test for settleable solids proposed by Dr. Buswell.

Suspended Solids.—Sewage solids cannot be dried at 180° C. because organic matter is charred at this temperature. On the other hand not all of the water held by inorganic salts is driven off at 103° C. We have made tests which indicate that Fe_2O_3 may hold considerable water (as $Fe_2(OH)_6$) when present in sewage solids. Loss of this water on ignition is reported as volatile matter. Further study is certainly required of the actual significance of results reported as volatile suspended solids, since a variable proportion of the so-called volatile matter is H_2O or CO_2. The same caution is of even more importance for sludge, which may also contain $(NH_4)_2CO_3$, lost on drying even at 103° C.

Nesslerization.—Turbid solutions occasionally cause difficulties in the nesslerization of ammonia distillates. We have been successful in preventing this difficulty by adding, before nesslerization, 10 drops of a solution containing 500 grams of Rochelle salts in 1 liter of distilled water.

Additional Methods.—Methods for the colorimetric determination of the pH of sewage and sludge have been studied and perfected. The best of these should be recommended, with a word of caution about the use of permanent standards of colored glass, which should be used only when it is impossible to use buffer solutions.

Reports of analyses should be more specific. Organic and ammonia nitrogen should be clearly differentiated; the time and temperature of B. O. D. tests should be specified, preferably 5 days at 20° C.; results should not be reported out to decimals representing fictitious accuracy.

A method for phosphoric acid in sludge should be included in the new edition. Methods should be included for phenols in coke-plant wastes, sewage and effluents, as well as a more sensitive method for water supplies.

A method might be included for separating mineral oil from animal or vegetable fats or soaps.

Since *Standard Methods* has always included only approved and time-

tested methods, and many provisional tests of practical use are required in sewage work, it might be desirable for our Federation of Sewage Works Associations to inaugurate a comprehensive investigation of methods of sewage analysis, either by appointment of committees or referees, who would plan and carry out the research necessary to develop and perfect the methods.

Comments by A. M. Buswell and G. E. Symons*

New Method for the Determination of Settling Solids.—Our attention was called to this question a few years ago by some apparently inconsistent results on the effect of different sedimentation periods on the removal of solids in Imhoff tanks. The amount of solids removed by the Gooch solids test did not appear to check the solids removed, as indicated by the residue on evaporation determination, nor did they accord with any consistency with the results which might be expected from the changes in the detention periods.

Theriault[1] had previously called attention to difficulties in the determination of the suspended solids with the use of the Gooch crucible.

More recently it has been observed that gas yields per capita per day in plant installations have been about 50 per cent of the yield to be expected. This expected yield was based on laboratory data of carefully controlled experiments on the gas yield per unit mass of domestic sewage sludge. Since these plant data on gas yields have been calculated from the Gooch solids or total residue determinations it would appear that these determinations are in error as much as 50 per cent.

In making the determination of solids in sewage there are really two sampling errors. In the first place the individual portions which are taken at, say, hourly intervals are usually from 100 to 300 cc. in volume and the vessel which is used in collecting the sample is seldom over five inches and frequently not over an inch to an inch and a half in diameter. A sampling vessel of this sort will obviously fail to pick up the proper share of the larger objects. If a large sampling vessel is used, it is necessary to pour off the proper proportion into the smaller container and from the writers' observation it is impossible to avoid a certain amount of sedimentation or flotation of large particles, no matter how vigorously the sample in the large vessel is stirred. The tendency is, therefore, as Theriault states, to obtain too low a proportion of large particles in the raw sewage sample.

A second sampling error occurs when the portion for analysis is taken out from the composite sample. The composite 24-hour sample of sewage commonly amounts to two to three liters. From this, 100 cc. is withdrawn

* *Illinois State Water Survey, Urbana, Ill.*

for the determination of total solids and 50 to 100 cc. for the determination of the suspended solids (Gooch). In withdrawing these relatively small portions the tendency will almost always be to obtain too low a proportion of larger particles. These errors will affect the sample of raw sewage almost exclusively.

The obvious way to avoid these sampling errors is to increase the size of the sample. If it were possible to determine the total amount of fresh solids which settle out in a sedimentation tank, that would appear to be the most accurate method of determining the effect of the sedimentation process. Data are available on the amount of solids removed by plain sedimentation, but we have not been able to find any extensive tests where these have been correlated with laboratory determinations of the solids in the influent and effluent. All the data that have been examined showed that the sludge removed as calculated from the solids determination on the influent and effluent may be as much as 60 per cent low when compared with actual sludge removed.

It was to more nearly correlate the amount of sludge removed by sedimentation with laboratory data that the new method described herein was devised. An experimental *Nidus* tank offered an excellent means of testing the determination and comparing it with the total solids and suspended solids determinations, since samples of the influent and effluent could be obtained and the actual sludge settled out could be withdrawn and measured. The per cent of solids of the sludge was determined and from it was calculated the pounds of dry solids removed. Total residue and suspended solids and settling solids were determined on the influent and effluent, and from the difference between the influent and effluent the amount of sludge removed was calculated.

Over a period of thirteen months, the data show that the solids removed as calculated from the Gooch solids is from 50–65 per cent low. According to the total residue determination 23.7 per cent more solids were removed than were actually removed. The new settling solids test gave data which was only 6.5 per cent low compared to the actual sludge removed.

Procedure.—A liter of the sample is placed in a glass tube $1^3/_4$ inches in diameter and about 3 feet long, set in a vertical position and fitted with a rubber stopper in the lower end. After one hour of quiescent settling, the sample is given a slight rotary motion to loosen any particles attached to the sides of the tube. Following another hour of settling, the supernatant liquor is siphoned down to a residual volume of about 50 cc. of liquor and settled solids. Removal of the stopper allows the residual liquor and solids to be transferred to an evaporating dish. The measuring cylinder is then rinsed with not more than 50 cc. of distilled water and this wash water is used to rinse out the settling tube and then added to the liquor in the evaporating dish, in order to avoid losing solids which adhere

to the measuring cylinder. The liquor is evaporated on a steam bath and the residue is weighed. The weight multiplied by 1000 gives this residue in parts per million. A correction must be applied to this result, because of the dissolved and non-settling solids contained in the liquid portion of sample. This correction is worked out as follows:

Let x = weight of settling solids in 1 liter of original sample.
Let y = weight of non-settling solids plus dissolved solids in 1 liter of original sample.
Let R = weight of total residue in 1 liter of original sample. (Note: This is equal to 10 times the weight of the residue on evaporation as determined on a 100 cc. sample, as described in correction for dissolved solids.)
Let w = weight of residue in residual volume of solids and liquor determined as described in the procedure, on a 1-liter sample.
Let v = volume in cc. of residual volume of solids and liquor, remaining after siphoning.

Then: $$w = x + \frac{v}{1000}(y)$$

But: $$y = R - x$$

Hence: $$w = x + \frac{v}{1000}(R - x)$$

$$w = x + \frac{v}{1000}(R) - \frac{v}{1000}(x)$$

$$x\left(1 - \frac{v}{1000}\right) = w - \frac{v}{1000}(R)$$

$$x = \frac{\left(w - \frac{vR}{1000}\right)}{\left(1 - \frac{v}{1000}\right)}.$$ If v is 50 cc. this formula simplifies to $x = \frac{w - 0.05R}{0.95}$.

Instead of substituting for "w" and "R" the actual weights, the results in parts per million may be substituted.

Accuracy of Results

1. By using a large sample, the second sampling error mentioned above is eliminated.

2. The vertical sides on the settling tube and stirring gently once or twice during the 2-hour period eliminate adhesion of settling solids to the sides.

3. Siphoning down to a residual volume of about 50 cc. can be done with sufficient care to avoid disturbing the settled solids.

4. At times, a small amount of solids float on the surface, but on stirring these solids gently, a large portion of them settles to the bottom.

5. Duplicate determinations on various samples have shown that checks to 1 per cent can be obtained no matter what residual volume of liquor containing the settling solids is used so long as this volume is known and care is taken not to disturb the solids in the bottom of the tube during siphoning.

6. The test as described eliminates any error due to volatile compounds and gives a true estimate of the amount of settling solids, when used in sludge digestion experiments.

When checked against the actual sludge removed, the Gooch solids data were 50–65 per cent low, and the total residue data 23–25 per cent high, while the settling solids data were only 6–7 per cent low. The fact that the residue on evaporation gives high results is not in accord with expectations nor previous data. An examination of the daily data and operating conditions gives an explanation of this apparent anomaly. It was noted that there were a great number of days when, according to the total residue determination, there was exceptional removal of solids and other days there were negative removals. These negative removals usually followed the days of high removal. This led to an examination of the daily analyses. It was found that on the days of high removal there was also an apparent high removal of chlorides, and vice versa.

Since the city water in Champaign-Urbana is quite hard, there are many zeolite water softeners in the twin cities, and when these are charged there would be an introduction of a great amount of brine into the sewage. This coupled with the fact that our operating condition did not permit 24-hour sampling made it necessary to proportion the 10 p.m. and 6 a.m. samples to approximate the amount of sample that would have been collected during the interval. The practice was based on the assumption that the concentration changed little during that time. The practice no doubt led to the anomalous results obtained on chloride removal.

A check of the data, calculating the chlorides to sodium chloride and correcting for the same, gives results which are much more comparable and do not vary widely.

It was noted that with three exceptions there were no negative results obtained from the settling solids determinations during the entire study. On the other hand there were 35 days in 13 months when this determination showed excessive removal. These, and the negative results, occurred on days when similar results were obtained from the total residue determination. This would indicate that though the settling solids determination is corrected for dissolved solids, there are times when the correction is not quantitative. It might be expected that the determination would be subject to such an error, since the correction is based on the total residue determination.

While the settling solids determination when checked against actual sludge removed gave anomalous results only 35 days out of 13 months, the total residue determination gave erroneous data more than half of the time. The data shows that the results calculated from the settling solids determination are more consistently comparable to the actual sludge removed than the results calculated from the residue on evaporation.

The above statement presents a strong argument in favor of the method. It is apparent from the data that this method has a great advantage over

the Gooch method (which may be from 50–65 per cent in error) for determining suspended matter. The method also offers a convenient means of determining the amount of liquefaction during sludge digestion.

This determination has been called *settling solids*[2] to distinguish it from settleable solids as determined in an Imhoff cone. The method was originally worked out in conjunction with Dr. A. L. Elder and Mr. C. V. Erickson, formerly of this laboratory. Additional data collected when the sampling procedure has been improved here, or at other plants where facilities for actually measuring the sludge removed are available, will do much toward furthering information on the applicability and accuracy of the determination.

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A Method for the Determination of Sludge Drainability.—The draining properties of sludges have been used as an index of the degree to which digestion has proceeded,[1, 2] for any method of measuring the sludge drainability is a method of measuring the ripeness of the sludge. The following method has been worked out and has been used with success on sludges for single and two-stage digestion units.

The apparatus used in the determination consists of a ring stand and ring supporting a 9-inch funnel, the stem of which extends into a 100-ml. graduate. Placed in the funnel is an 8-inch standard screen scale, having 28 meshes to the inch or an opening of 0.0232 inch. One-half an inch of clean Ottawa sand of an effective size greater than the screen opening is placed in the screen. On the sand is placed a circular piece of copper screen (10 meshes to the inch and $7^1/_2$ inches in diameter). This screen is used to facilitate the removal of a sample of sludge after the determination is complete. Samples so removed for moisture determinations are free from sand and hence free from errors that would be caused by the presence of sand. A large watch glass is used to cover the screen scale to reduce the loss due to evaporation to a minimum.

The sand is moistened with water, care being taken not to disturb the smooth surface. The sand is allowed to drain for fifteen minutes or more until no water drains from the sand when tipped in any direction. The screen with the moist sand is weighed on a pan balance and then placed in the funnel such that the sand is perfectly level. Sand holds about one-half of its volume of water. By filling the sand with water before starting the determination, draining of the sludge starts immediately and no correction has to be made at the end of the determination for the water held in the sand.

A liter volumetric flask or graduate is filled with sludge and the flask plus sludge is weighed on the pan balance. The sludge after shaking is then carefully emptied onto the sand and the time noted. The total volume of liquor drained is recorded after the following intervals of time; three, six, twelve, twenty-one, thirty and forty-five minutes, and one, one and one-half, two, two and one-half, three, four, five, six, seven and eight hours. Occasionally slow draining sludges may be allowed to drain a longer time, but most sludges practically cease to drain in seven hours.

The empty flask containing that sludge which sticks to the sides is weighed and the difference between the weight of the empty and the full flask is taken as the weight of the sludge sample being drained. A sample of the sludge is taken for a determination of the moisture content at the same time the sludge is poured on the sand. From this determination and the weight of the sample poured on the sand the original weight of water in the sample draining is calculated. The specific gravity of the liquor draining is assumed to be 1.00 so that the volume drained (in cc.) represents the weight of the liquor drained. After the test is complete and before the sample for final moisture content is taken, the screen plus sand plus sludge is weighed on the pan balance. This weight less the weight of the screen and wet sand equals the weight of the sludge. A quick check on the evaporation may be had by subtracting the weight of the sludge after draining from the original weight of the sludge sample. The difference between the two should equal the liquor drained. Any discrepancy is due to evaporation and the error is distributed. From a per cent moisture determination on the final sludge and the weight of the sludge, the amount of moisture in the sludge cake is calculated. This value subtracted from the original weight of water in the sludge should equal the amount of water drained. The former method is probably more accurate than the latter, though close checks have been obtained. The discrepancy between the two methods of calculation is due to the error in sampling the sludges for the moisture determination.

The total weight of liquor drained in any interval of time divided by the weight of moisture in the original sample gives the per cent of the original moisture draining in that time. By plotting the percentages of the original moisture that drained in time "t" against the time, a curve representing the drainability of the sludge is obtained. In this manner, the differences in original moisture content of the sludges are eliminated as variables. The curves obtained are of the type of a first-order rate of reaction curve and when compared give a good idea of the loss of hydrophyllic properties of a sludge.

It has previously been the custom as reported in Illinois State Water Survey *Bulletin* No. **39** (in press) to plot the per cent of liquor remaining

of the total liquor drained against time. This left the original and final moisture contents of the sludges as variables such that they necessarily had to be included on the curve before any conclusion could be drawn regarding the ripeness of the sludge. Though the new method of plotting has removed this variable it is still the custom to append the original and final moisture contents to the data curves. The volume of sludge is also determined by centrifuging a sample for thirty minutes at 1200 r. p. m. and reading the volume occupied by the sludge. This datum is also appended to the curves.

As determined in this manner, the sludge drainability determination offers a method of following the course of digestion and determining the ripeness of a sludge. We recommend it as a test to run in comparison with other data. It may eventually be developed and simplified to such a point that it may be made a means of defining ripe sludge.

References

[1] Babbitt & Schlentz, Vol. I, Univ. of Ill. Expt. Sta., *Bull.* **198** (1929).
[2] Buswell, *et al.*, Ill. State Water Survey, *Bull.* **29** (in press).

Comments by Max Levine*

With reference to the chemical method of *Standard Methods*, I feel that those relating to sewage need much revision. A student has been working on nitrate determination. Part of this work has been published in a recent number of the *J. A. W. W. A.* Since then we have determined the reaction limits (pH) within which nitrites are destroyed by evaporation to dryness, without affecting the nitrates. I am not in a position to write this work up in detail. The method is briefly this:

1. Add NH_4Cl to give a concentration of 1000 to 2000 p. p. m.
2. Make the test solution neutral or slightly acid to phenolphthalein.
3. Evaporate to dryness.
4. Dissolve in nitrate-free water.
5. Evaporate to dryness again.
6. Dilute, make strongly alkaline, boil off the NH_3.
7. Proceed as for the standard reduction method for NO_3.

The value obtained for NH_3 is a direct measure of the NO_3 content, the nitrites having been destroyed by evaporation in the presence of the NH_4Cl.

We found the method to give satisfactory results in the presence of as much as 50 p. p. m. NO_2, and in the presence of considerable organic nitrogen (up to 100 p. p. m.).

* *Prof. of San. Bact., Iowa State College, Ames, Iowa.*

Comments by W. S. Mahlie*

I find no mention made of the universally used Imhoff cone method for settleable solids by volume, or the non-settleable suspended solids by weight.

The determination of H_2S is not mentioned in the sewage section although a method is included in the section on water analysis. The same thing is true for pH value. A method for H_2S, applicable to sewage and sludge, is especially needed. At our own plant we recently tried to obtain H_2S values in some sludge. It appears that the usual practice is to work on the supernatant liquor after settling about one-half hour, using the iodine-consumed method as outlined in the water section of *Standard Methods*. We took the sludge without settling, added an excess of iodine, centrifuged the mixture, and then titrated the excess iodine. It appears that the solids in the sludge have iodine-absorbing properties which are not included when working on the supernatant. It also appears that ammonia affects the iodine-consuming value unless the sewage or sludge is first acidified.

In the method for total organic nitrogen, optional procedures are given, but all methods are alike in one respect, and that is in the first step, in freeing the sample from ammonia. Now, in the method for free ammonia, mention is made that some hydrolysis of the nitrogenous matter may take place in distillation. In view of this and my own experience, I always include all the ammonia, by starting the digestion on the sample as received, and later correcting for the ammonia found in another portion of the sample.

None of the methods have had more discussion than that for B. O. D. By all means a standard dilution water should be recommended.

It might be desirable to include Sierp's method for B. O. D. on sludges and other materials having a very high demand, but for routine plant control, too much glassware is required. I believe no harm would be done if the sodium nitrate method for B. O. D. were eliminated altogether.

I notice that in the paragraph devoted to sampling sewage, it is recommended "that samples be taken each hour, in some cases at half-hour intervals." While this is desirable it is hardly practical for plant operation. I believe it would be well to call attention to the varying strengths of sewage as affected by the various days throughout the week.

In the method for nitrites, which is the same as in water analysis, the preparation of a suitable standard from silver nitrite is somewhat cumbersome. I have been using sodium nitrite direct, after first determining the amount of nitrite by oxidimetric methods. I have purchased a number of samples of silver nitrite and no two of them were alike in color, consequently I did not feel that they were of constant composition.

* *Chemist-in-Charge, Water and Sewage Purification, Fort Worth, Texas.*

I am especially interested in the desirability of including explanatory material. I have felt this was one of the shortcomings of the text, since there are a great many men using *Standard Methods* as if it were a cook book, and some erratic conclusions have been reached due to failure to understand the methods. If this explanatory part cannot be included in *Standard Methods*, it might be a good plan to run a series of articles in THIS JOURNAL from time to time.

Two Devices for the Removal of Sludge Samples at Different Depths. *Kl. Mitt. Ver. fur Wasser-, Boden-, und Lufthyg.*, 1930, **6,** 54.—Descriptions and diagrams are given of arrangements for the withdrawal of sludge samples at different depths, designed by H. Blunk and F. Fries, respectively. The apparatus designed by H. Blunk is constructed for use with Emscher tanks and consists of a metal cylinder, the two ends of which are closed by a double piston. Before the apparatus, which is weighted with lead, is lowered, the piston is displaced downwards so that the upper plate is at the lower end of the cylinder. The lower plate of the piston travels between guiding rods extending below the cylinder. At the desired depth the piston is drawn up by a lever and the sample drawn into the self-closing cylinder, the piston being prevented from further movement by a clip on one of the guiding rods.

The apparatus designed by F. Fries is completely water-tight, and can therefore be adapted for removing samples of water as well as sludge. It consists of a weighted metal cylinder which can admit a means of pressure through a specially arranged system of tubes, and which can be opened or closed by means of a second cylinder containing a piston attached to the receiving cylinder so that the receiving cylinder opens or shuts according as the pressure is applied to the piston from above or below. A multi-way stop-cock is provided above the plant for regulating the pressure cylinder. Water has proved successful as a means of pressure but any other liquid or a gas can be used instead. The manipulation of the apparatus is simple, the pressure for opening and shutting being supplied by a double tube.—Abst. No. **593,** *British Summary of Current Literature*, Vol. III, No. 5, May, 1930.

Control of Filter Growths by Chlorination[1]

BY E. E. SMITH[2]

Chlorine has long been associated with the subject and art of water treatment and has been the faithful servant of the water works operator in obtaining a pure and wholesome water. Just as the water works operator can produce a pure water from a polluted supply, so can the sewage-treatment plant operator produce a purified and stable effluent from the same water that the water works operator furnishes, except that by its passage through the homes and industrial centers of the city it has become grossly polluted. By analogy it would seem that chlorine should be useful in battling disease-producing bacteria in sewage treatment as it has in water treatment. Our experience has shown that chlorine may also be of further service to the sewage works operator.

The Imhoff-tank trickling-filter plant of the Sanitary District of Elgin has been in operation since June, 1927. The population tributary to the plant is approximately 35,000. Sewage is primarily domestic, although some milk-products wastes are present. The flow averages approximately 4 m. g. d., or 114 gallons per capita per day. The trickling filters are 1.5 acres in area, and 8 ft. deep. The top filter stone passes a 2-in. screen but is retained on a 1-in. mesh. All stone was rescreened and washed before being placed.

During the early spring of 1929, pooling was noticed on the surface of the trickling filters. As it appeared in only a few spots and the film was thin it was thought that possibly during the spring slough this condition would clear itself. A short time later the slough occurred, all traces of pooling vanished and the beds appeared to be in a very clean condition. The filters worked very efficiently during the summer and fall of 1929 but by January of 1930 signs of pooling were again noticed on the beds. This caused some apprehension as the weather was cold, with temperatures as low as 16 degrees below zero. As time went on the pooling became worse and in February it was so bad that large sections of the bed were covered with sewage. (Figures 1, 2 and 3.) During this period data and information were being collected from all possible sources on the subject of pooling and its remedy, and it was finally decided to try chlorine.

The pooling was caused by a slime of gelatinous, plant-like growth that sealed the surface between the stones and filtered and held the scum and colloidal matter of the Imhoff-tank effluent.

On February 1, 1930, a manual-control vacuum-feed chlorinator of 300 pounds per day capacity was ordered from Wallace and Tiernan Com-

[1] *Presented at the Third Annual Meeting of the Central States Sewage Works Association, Springfield, Ill., June 9, 1930.*

[2] *Superintendent, Sanitary District of Elgin, Illinois.*

FIG. 1.—Elgin Filters, Feb. 19, 1930.

FIG. 2.—West Filter, Feb. 19, 1930.

FIG. 3.—East Filter, Feb. 19, 1930.

Fig. 4.—Elgin Filters, April 4, 1930. After Chlorination of East Filter, to the Right, and before Chlorination of West Filter, to the Left.

pany, Incorporated. As they considered this somewhat as an experiment, the machine was placed on a trial basis.

The chlorinator was installed and ready to operate on March 5, 1930. By this time the pooling was so bad that the east half of the filter was approximately 75 per cent covered by sewage.

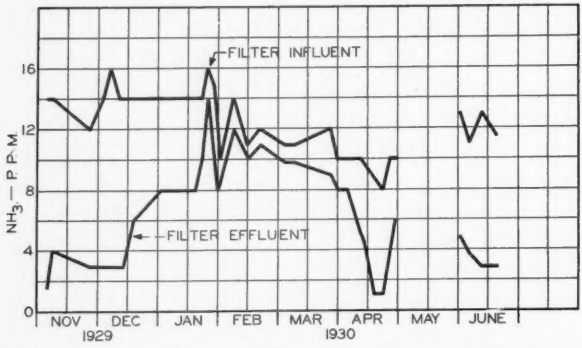


FIG. 5.—Ammonia Nitrogen in Influent and Effluent of East Filter. Chlorination Started March 5, 1930, and Ended March 31, 1930.

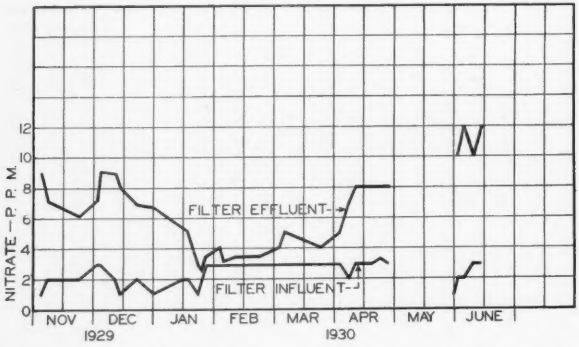


FIG. 6.—Nitrate Nitrogen in Influent and Effluent of East Filter. Chlorination Started March 5, 1930, and Ended March 31, 1930.

The Elgin filters are built in duplicate, with two dosing tanks and two filter beds, therefore it was decided to dose chlorine on only one bed and to observe the results before chlorinating the other bed.

Chlorination of the east filter was started March 5, 1930, at the rate of 300 pounds per day. The rate of filtration was 2.8 m. g. per acre per day. Chlorination was continued for three days and nights. After this, chlorine was dosed only during the hours from 10 p. m. to 8 a. m. of the following

day. This saved considerable chlorine as the organic load was less during these hours, and residual chlorine tests had shown a very small amount of chlorine at the nozzle during the daytime.

At the beginning of chlorination the chlorinator was set to deliver 20.6 parts per million. At this time the equipment for the determination of residual chlorine had not been received, therefore no record was obtained of the applied sewage. On March 10th the machine was set to deliver 13.2 parts per million. At this rate of flow the amount in the applied sewage at the nozzle varied from 6 to 9 parts per million which was considered ample for the purpose of disintegration of the filter slime. At a later date the rate of delivery was reduced to 5.2 parts per million at which time the amount in the applied sewage equaled 2.0 parts per million. This was con-

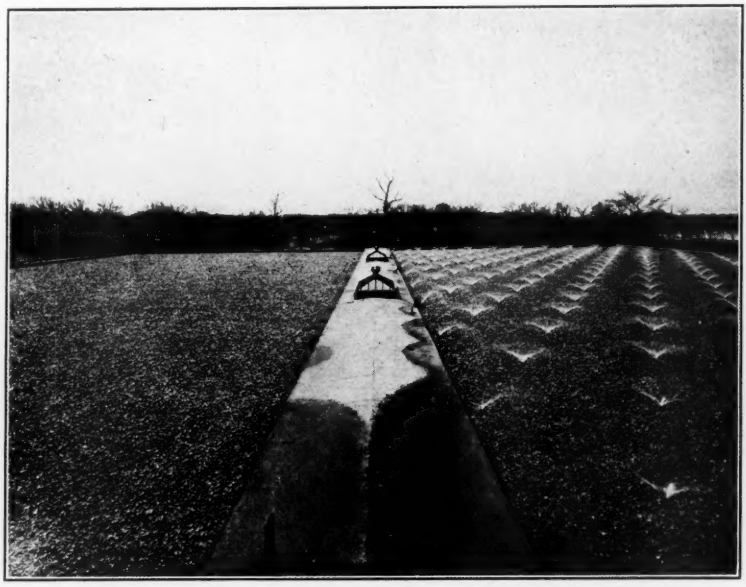


FIG. 7.—Elgin Filters, April 24, 1930. After Chlorination of Both Filters,

tinued for only two nights and then the rate of delivery set at 11.2 parts per million with a residual in the applied sewage of 4.0 to 6.0 parts per million. During the entire period of chlorination the chlorine absorbed by the organic matter in the sewage, in passing through the dosing tank and distribution system, was from 4 to 7 parts per million.

From the beginning of chlorination for a period of two weeks residual chlorine was obtained in the filter effluent to an amount of 1 to 4 parts

per million. This was because the sewage containing the chlorine ran over the surface of the bed and down the side walls to the drains. After the chlorine had caused disintegration of the growth and the liquid began to percolate through the bed, no residual chlorine was found in the effluent. (Figure 4.)

Analyses of the influent and effluent of the east bed are shown in Figures 5 and 6.

Results obtained by chlorination of the east bed were so satisfactory that the chlorination of the west bed was started April 2, 1930. Similar action and results were obtained after a short time. (Figure 7.)

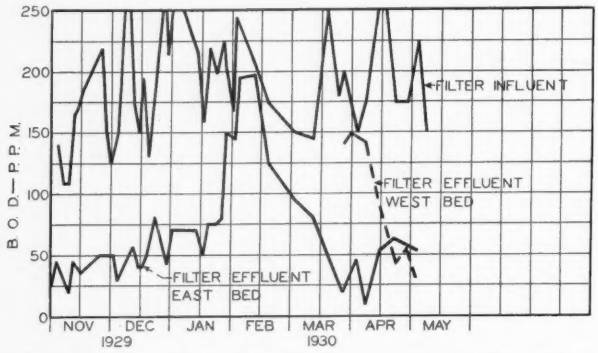


FIG. 8.—B.O.D. of Influent and Effluents of East and West Filters. Chlorination of East Filter in March, 1930 and of West Filter in April, 1930.

In addition to the elimination of pooling, the chlorine loosened and killed off the growth that had accumulated in the distribution system of the filters, and after chlorination the sprays were more even and vigorous. The quality of the effluent was greatly improved after the beds became open, and the B. O. D. of the effluents decreased to approximately the same concentration as in the previous spring. (Figure 8.) Analyses are made on a single sample, which is probably more concentrated than the average 24-hour composite.

The test of the ability of chlorine to disintegrate the film on the filter was a very severe one as the film had reached a maximum thickness of three inches. This meant that larger amounts of chlorine were needed than would have been necessary had a chlorinator been available earlier in the stages of ponding. During this period of chlorination, a total of 4500 pounds of chlorine was used for the filter of 1.5 acres in area, which was equal to 3000 pounds of chlorine per acre. With chlorine costing 7.9 cents per pound the cost was $237 per acre.

From our experience at Elgin we agree with others that have used chlorine for filter control, that the chlorination of the night flow is by far most desirable and economical.

Chlorine for Elimination of Nuisance from Creamery Wastes.—In a paper presented before the Arizona Public Health Association, Mr. James Minotto has described the use of chlorine for deodorizing the wastes from the Mission Dairy of Phoenix, Arizona. No sewerage facilities were available. The plant receives 7000 gallons of milk and cream per day, which is processed into pasteurized milk and cream, buttermilk, butter, cheese, condensed skim milk and ice cream. Approximately 60,000 gallons of wash water is used.

The wastes are treated with chlorine at the dairy. A 7000-gal. septic tank is provided to take care of peak loads, and from this the waste is pumped one mile to the disposal field, 10 acres in area. The discharge pipe has seven outlets controlled by valves, so that the waste can be turned into eight furrows, which are filled in twelve hours, and plowed under every other day. The soil is fairly tight and uniform, with the groundwater at a depth of 30 feet. Annual rainfall averages only 7.75 inches.

Sixty parts per million of chlorine has been used, but it is planned to reduce this to 25 or 30 p. p. m. With the large amount a slight odor of chlorine is apparent.

The capital outlay for a chlorinator, septic tank and sewer system was $2500. Operating expenses total $1728 per year, of which the cost of chlorine is $518, at 9.5 cents per pound. The cost of operation averages $4.75 per day or 16 cents per ton of milk handled.

More than six months experience indicates that offensive odors can be eliminated by this procedure.—JAMES MINOTTO. *Municipal Sanitation*, **1**, 406, July, 1930.

Massachusetts—the Cradle of Public-Health Engineering[1]

BY HARRISON P. EDDY[2]

Introduction

The term "public-health engineering" may be said to signify the science and art of applying, economically, the laws, forces and materials of nature for the health, comfort and convenience of man. This branch of engineering, which deals with problems relating to the protection and preservation of the health of communities, embraces many aspects of water-supply engineering, the sanitation of dwellings and other buildings, the sewerage of cities and towns, the drainage of land, the disposal of sewage, the collection and disposal of municipal refuse, and other works for safeguarding the public health. While it would be unwise to say that any of the divisions of this field are unimportant, it is fair to state that a very important part in preserving the health of the public today is played by works for the supply of potable water and for the safe disposal of liquid wastes. In the development of the art of building and operating such works, Massachusetts has played a leading role, in that many of the basic principles were recognized, tested and explained in this State.

Water Supply

First Works in America.—The first water works of which there is record in what later became the United States was built in Boston in 1652. At the May session of the General Court of the Colony, held in that year, on petition of the inhabitants of Conduit Street in Boston, "The Water Works Company" was incorporated for building a reservoir, or "conduit," as it was called, erroneously, and provisions were made for the use of the water in case of fire. It appears that the "conduit" was about 12 ft. square built to hold water conveyed to it by pipes leading from neighboring wells and springs, for the purpose of extinguishing fires and supplying the inhabitants dwelling near it with water for domestic purposes. The "conduit" was situated in a square formed by the junction of the present Elm Street and Union Street, not far from Dock Square.

This early attempt on the part of a water-works company to obtain a supply for a community was followed by public wells dug by the Dutch in New York in 1658, and subsequently by works in many other places. In Boston, the General Court of Massachusetts gave a charter in 1795 to the "Aqueduct Corporation" to bring water from any part of the town of Roxbury into Boston. During its period of maximum prosperity this

[1] *Presented at Second Annual Meeting, New England Sewage Works Association, Boston, April 15, 1930.*

[2] *Metcalf & Eddy, Consulting Engineers, Boston, Mass.*

company supplied about 1500 houses with water from Jamaica Pond. Finally in 1848, a municipal water supply was introduced into Boston from Lake Cochituate.

Beginnings of the State Board of Health.—In the year 1869, the Massachusetts legislature created a Board of Health, which, in the words of its first chairman, Dr. Henry I. Bowditch, was "the first state board of health established by any American state; at least, with objects as extensive as those now given to our charge." The Board was directed to take cognizance of everything tending to public health and to endeavor to eradicate everything tending to public disease and death. It was also directed to diffuse among the people a knowledge of the means of obtaining individual and public health and of preventing disease. It was not long before several definite investigations were under way. In the light of our present knowledge, some of the conclusions reached in the early studies are of interest.

The second annual report made in 1871 contains a paper on the causes of typhoid fever in Massachusetts, written by the secretary, Dr. George Derby. It must be remembered that at that time the world did not have adequate knowledge of the nature and means of transmission of communicable diseases. Dr. Derby reported that "the single continuous thread of probability which we have been able to follow in this inquiry leads uniformly to the decomposition of organized (and chiefly vegetable) substances as the cause of typhoid fever as it occurs in Massachusetts. Whether the vehicle be drinking-water made foul by human excrement, sink drains or soiled clothing; or air made foul in enclosed places by drains, decaying vegetables or fish, or old timber, or in open places by pigsties, drained ponds or reservoirs, stagnant water, accumulations of filth of every sort, the one thing present in all these circumstances is decomposition."

The 1871 report contains also a paper on Mystic Pond water, written by the secretary, assisted by William R. Nichols, who was Professor of Chemistry at the Massachusetts Institute of Technology. The science of water analysis was then in its infancy, and Professor Nichols laid the foundations for the future work of the Board in this field. To quote from the paper, it shows how a "pollution," consisting of discharges from tanneries, glue factories and a chemical works, "which, at first sight, it would seem must necessarily cause contamination to the drinking water of several towns is rendered by the alchemy of nature, at present at least, comparatively harmless. At the same time, it forewarns us of what must certainly occur if we allow the present impurities of Mystic Pond to be increased. For a still further reason, the Board urges removal even of the present small nuisance, because the very filth, which tends to contaminate, might be saved and used for beneficial purposes, whereas it is now lost and at the cost, perhaps, of human health and life."

Board Empowered to Protect Purity of Inland Waters.—In the year 1886, the legislature passed an act to protect the purity of inland waters, which conferred new powers upon the State Board of Health. Briefly, the act placed in the hands of that body the general oversight and care of all inland waters, directed that examinations of the waters be made to ascertain whether they were adapted for use as sources of domestic supply, or likely to imperil the public health, and that recommendations be given as to the prevention of pollution. Authority was given to employ expert assistance and to conduct experiments to determine the best practicable methods of purification of sewage.

In order to carry out the provisions of this act an engineering department was created, with the late Frederic P. Stearns as Chief Engineer. The following year a regular system of chemical analyses was organized under Dr. Thomas M. Drown, Professor of Chemistry at the Massachusetts Institute of Technology.

Lawrence Experiment Station.—As a further step toward carrying out the provisions of the act just mentioned, and largely due to the initiative of Hiram F. Mills, the engineer member of the State Board of Health, an experiment station was established at Lawrence in 1887. The work done at the Lawrence Experiment Station, on methods of purification of water and treatment of sewage, has been one of the principal reasons why the reports of the Massachusetts State Board of Health are found on the book shelves of engineers not only in this country but throughout the world.

One of the outstanding characteristics of the investigations at Lawrence was that they furnished data upon the engineering, chemical and biological phases of the processes of nature artificially employed. Such thoroughgoing and unusually well-coördinated data have had much to do with the development of public-health engineering during the past forty years or more.

A few years before the experiments at Lawrence were begun, the germ theory of disease had been established through the work of Pasteur. During 1891 and 1892, use was made of the new science of bacteriology at Lawrence in an investigation which demonstrated the ability of ordinary sand filters to remove typhoid fever germs from water. This was a matter of more than usual importance in the Merrimack valley, where the Lawrence water supply intake is only 8 miles below the Lowell sewers.

Lawrence Water Filter.—In the late summer of 1892 Asiatic cholera appeared on vessels quarantined in New York harbor, and, under these circumstances, it was not difficult for Mills to obtain from the City Council of Lawrence authorization for the construction of a sand filter for the purification of the municipal water-supply. This filter was completed in 1893 and embodied in its design the application of many of the data derived at the State Experiment Station. Designed under Mills' direction, it was the first scientifically designed water-filtration plant in America, and its success

in reducing typhoid fever in Lawrence was notable. That the design has not been copied elsewhere has been due to the results of later studies, but the Lawrence filter became a landmark in the train of developments which characterized the improvement in the quality of water supplies in this country.

Chestnut Hill Biological Laboratory.—To the Massachusetts State Board of Health, as already stated, belongs the credit of having begun as early as 1887 a systematic examination of all the water supplies of the State. Two years later, the State Board of Connecticut began a similar but less extensive survey. In 1889, the Water Board of the City of Boston established at Chestnut Hill Reservoir a laboratory for the systematic study of the biological character of the various sources of water supply, this being the first municipal laboratory for biological water analysis in this country. For the first 8 years of its existence, the laboratory was conducted by George C. Whipple under the general direction of Desmond Fitzgerald. In 1893, a small laboratory was established by the Public Water Board of the city of Lynn.

In 1897 Mt. Prospect Laboratory, connected at first with the Department of Water Supply of Brooklyn, N. Y., and shortly afterward with all the water supplies of Greater New York, was established. It was devoted to general water analysis, and microscopic examinations formed an important part of the routine and special work. From 1897 to 1904 Mt. Prospect Laboratory was operated under the direction of Whipple, who there completed 15 years of thorough-going investigation into the various factors related to tastes and odors in surface-water supplies. Building upon the foundation which he laid, this laboratory has produced outstanding work in the control of algae in water.

Similar biological work has since been undertaken by boards of health and water departments in all parts of the world.

Sewerage and Sewage Disposal

Early Sanitary Regulations.—Not only in the field of water supply but also in sanitation did the inhabitants of Boston make an early start. In 1647, only 17 years after the settlement of the town, the General Court of the colony passed an act making it "unlawful for any person to cast any dung, draught, dirt or anything to fill up the Cove, or to annoy the Neighbors, upon penalty of forty shillings." By the "Cove" was meant the general region of what is now Haymarket Square, Boston.

In 1702, an act was passed by the provincial government providing for the appointment of commissioners of sewers. This was followed in 1709 by another act, for regulating drains and common sewers, placing them under the direction and control of the selectmen of the town. Under this act, drains were built, repaired and owned by private individuals.

One of the first acts of the new city government of Boston, in 1823, was to assume control of the maintenance of existing drains and the building of new ones. Fecal matters were excluded by law until 1833. Even then, only liquid wastes were allowed, the admission of solid matters being prohibited.

First Reports on Sewerage and Stream Pollution.—The first important step forward in sewage treatment in this country was taken by the Massachusetts State Board of Health. In 1872, it was ordered to investigate the subject of sewerage, including the disposal of liquid wastes and the pollution of streams. This work was done by Prof. Nichols and Dr. Derby, who reported in 1873 that the water-courses were in danger of contamination, and that unless legislation to prevent the pollution of streams could be enforced better in Massachusetts than in England, the spoiling of the rivers of the State as sources of water-supply would be a question of time, of density of population and of their size.

In an appendix to this report, Phineas Ball, civil engineer of Worcester, reported on the opportunity and possibility of utilizing the sewage of that city. He set forth a plan whereby the liquid waste might be collected and conveyed to a point below the city, where there was an abundance of land suitable for the installation of filter beds on a large scale, or where the waste water might be employed for purposes of irrigation.

In 1876, James P. Kirkwood, another engineer, made a report upon stream-pollution conditions in Massachusetts. He found that only nominal attempts had been made to prevent river pollution, because the machinery for doing this was cumbersome, expensive and slow in producing results. The contamination was not the same in the different river basins and in the same basin, in some cases, there were evidences of self-purification, by which the effect of pollution entering at one point gradually became less marked as the water passed downstream, and finally disappeared.

From the nature of these reports and from the professions of the men who made them, it will be observed that, even at this early date, Massachusetts was using the sciences of chemistry and engineering in attempting to solve public-health problems.

Boston Main Drainage Works.—In 1875 the City Council of Boston authorized the Mayor to appoint a commission of three members, two engineers and a person skilled in sanitary science, charged with the duty of preparing a plan for outlets and main lines of sewers for the future needs of the city. The commission, consisting of E. S. Chesbrough, Moses Lane and Dr. Charles F. Folsom, made its report the following year, advocating the general system of main drainage now in use.

As a result of this report, the legislature authorized the City of Boston to construct an intercepting sewer and outfall works discharging at Moon

Island in Boston Harbor. The works, which were completed and put into service in 1884, included one of the earliest sewage-pumping stations in the country. They were later, in effect, incorporated in a sewerage system serving the entire Metropolitan District, although the original works remain the property of the City of Boston.

Disposal by Dilution.—In spite of the fact that sewage disposal by dilution in large bodies of relatively clean water was the earliest method of disposal adopted by municipalities, it was not until about 1887 that investigation of the factors entering into it was made by Rudolph Hering, in connection with the problem of sewage disposal at Chicago. In Massachusetts, studies undertaken at about the same time and reported on by Stearns in 1890 established the limiting quantities of diluting water required and served as a basis of general practice for many years. More recently much information bearing on the disposal of liquid wastes by dilution has been accumulated. The studies made by the United States Public Health Service in connection with the Ohio and Illinois Rivers are particularly noteworthy.

Although seacoast cities and towns have seldom adopted methods other than that of dilution, it has often proved necessary, even with this method, to take precautions with respect to the location of outlets, so that pollution of shores and bathing beaches would be prevented. In the case of the Boston Main Drainage Works, for instance, special attention was paid to the location of outlets, and provision was made for detaining the sewage so that it might be released only at ebb tide.

Septic Tanks.—The sedimentation of sewage in tanks, without the use of chemicals, has been practised for many years, for the purpose of removing solid matter in suspension. The combination of the sedimentation of solids and their digestion, to render them inoffensive by bacterial action, is utilized in the septic tank, from which the modern Imhoff tank was developed. The septic tank is a sedimentation tank, designed and operated so as to foster the decomposition of the settled solids in the absence of oxygen. In this manner some liquefaction of the suspended solids is obtained, resulting in a reduction in the volume of solids requiring disposal.

Similar tanks were first used in America at the State Insane Asylum at Worcester in 1876, and later were installed at other places.

Broad Irrigation.—The treatment of sewage to render it inoffensive was undertaken even before the scientific principles involved began to be understood. The earliest method was that of broad irrigation, or the application of the liquid wastes to relatively level areas of land, where it could become absorbed and purified by the soil. To operate satisfactorily, large areas of porous and easily-drained soil were required, and, to avoid annoyance from flies and odors, it was necessary that the "sewage farms," as such tracts were called, be well isolated. Usually an effort was

made to utilize the manurial value of the domestic wastes by growing crops on the irrigated fields.

Among the first attempts of this sort in the United States may be mentioned the farm established at Lenox, Mass., in 1876, where both subsurface irrigation and broad irrigation were used; the broad-irrigation areas at the State Insane Asylum in Worcester, in 1876, and at Amherst, in 1881. Because of the large tracts of land required, however, and also for esthetic reasons, this method of treatment never was adopted widely in the United States and, with a few minor exceptions, is no longer in use.

Filtration Processes Studied at Lawrence.—Soon after the establishment of the Lawrence Experiment Station in 1887, a series of investigations of the nature of filtration was begun there. These studies, continued for many years, have undoubtedly been the leading source of inspiration and information along these lines, since the publication of the report on research work in 1890. The great value of this report was its clear demonstration of the biological nature of filtration. This was not an original discovery at Lawrence, but the elaborate experimental work done there threw much-needed light on leading phases of the subject. The filters were made of material ranging in size and character from peat, loam and very fine sand to large gravel. The sewage was applied intermittently and continuously, and from below as well as above the surface. The results were reported in great detail in each annual report, and the information concerning the action of bacteria proved an inspiration to many investigators and resulted in attempts in England to produce equivalent bacterial action in beds composed of materials other than sand. One of the developments from these attempts was the contact bed, a tank filled with broken stone, which is operated on the fill-and-draw principle. This type of filter has been used widely in England but only to a limited extent in the United States.

Intermittent Filters.—As a result of the Lawrence Experiment Station studies, there was developed in New England a modified form of broad irrigation, known as "intermittent filtration," by which crude or settled sewage is applied evenly to the surface of prepared areas of sand or other fine material a few feet in depth, underdrained by lines of tile with open joints. The process derives its name in part from the necessity of intermittent application of the sewage in order that the air, required for the life processes of microörganisms, the agencies of oxidation of the organic matters, may enter the voids of the sand. In New England, where soil conditions are favorable, this method was adopted promptly by many towns.

Trickling Filters.—The early experiments at Lawrence proved that the slow movement of sewage in thin films over the surfaces of stones, with air in contact, caused a great reduction in the organic nitrogenous matter

originally present, and in the bacteria. This demonstration of the value of coarse material for filters was followed in 1891 by the operation of a gravel filter, the liquid waste being applied in 60 to 70 doses a day. The coarse beds operated in this way, now called indiscriminately trickling filters, sprinkling filters and percolating filters, attracted more attention in England than in the United States, because of the local high cost of sand filters and the abundance of material from which coarse filters could be made. The field of their active development, therefore, was transferred to England. During recent years, many trickling-filter plants have been built in the United States.

Aeration of Sewage.—During the past 15 years, the activated-sludge process has been adopted in a number of places in the United States, in Canada and abroad. The process is the outcome of experiments on the aeration of sewage by numerous American workers, particularly the investigations at the Lawrence Experiment Station in 1912, which led to the work in England of Fowler and of Ardern and Lockett. This treatment consists essentially of aerating an admixture of sewage and aerated or activated sewage solids called sludge, and subsequently allowing the solids to settle. A high degree of purification can be secured in this way.

Sludge Digestion.—The septic tank had been found capable of reducing the volume of sludge after it had been removed from the flowing wastes by sedimentation, but the sludge was usually offensive, and the effluent from the tank was often malodorous, which was a drawback to its distribution over the filters, particularly by spraying. The ebullition of gases in these tanks also caused large quantities of solids to escape with the treated sewage, thus in a measure reducing the efficiency of treatment.

The idea of separating the settling solids from the digesting sludge, in order to avoid the objectionable features of septic tanks while taking advantage of the desirable ones, originated at the Lawrence Experiment Station in 1899. Since 1906 sludge digestion has been successfully carried out in the lower chamber of two-story, settling and sludge-digesting tanks, first used by Travis in England and later developed in Germany by Imhoff. More recently engineers have learned also to digest sludge successfully in entirely separate tanks, by the same alkaline methane fermentation that is observed in the lower chamber of two-story tanks when operating well.

Disposal Plant Operation.—Although much progress has been made in the art of sewage treatment, and many treatment plants have been built, there remains considerable lack of realization, on the part of the public and of municipal officials, of the necessity for continuous, careful and intelligent operation of such plants. Good management is absolutely essential to their success. Prior to 1900 only two such plants in the United States were under the control of resident technical operators, those

at Brockton and Worcester. By 1910 several others were under technical supervision, notably at Columbus, Ohio, Plainfield, N. J., and Reading, Pennsylvania. The operating records kept at these plants have been helpful in furnishing data upon which to base the design of other works. Since 1910 many new plants have been constructed, of which the larger have been provided almost invariably with technical operators.

Nation-Wide Influence of Work Done in Massachusetts

Experiments on Water Purification.—One of the ways in which Massachusetts aided materially in the development of public-health engineering was by training various young men as sanitary engineers, chemists and biologists during their employment on the staff of the State Board of Health. Some of these men later carried on important researches in various parts of the country, utilizing the knowledge and the investigational methods which they had acquired while in the employ of Massachusetts, and making this state's influence felt throughout the United States and even in Europe.

The early work of the Lawrence Experiment Station laid the scientific foundation for both water purification and the biological treatment of sewage. This was followed by studies of various processes of purification, principally different methods of filtration, of the following waters: Ohio River at Louisville, from 1895 to 1897; Allegheny River at Pittsburgh, in 1897 and 1898; Ohio River at Cincinnati, in 1898 and 1899; and Mississippi River at New Orleans, in 1900 and 1901. The experiments at the first three cities were conducted by two men who previously had been in charge of the Lawrence Experiment Station, while the New Orleans studies were under the direction of one of these men.

Although the experiments here mentioned were intended primarily to show the best practicable method of water purification under local conditions, it is difficult to estimate their vast influence on the development of public-health engineering. The value of such studies soon was recognized, and similar tests have been made since in many places. In this way, the art of water purification has been brought to its present state of development.

An interesting sidelight on the tests at Louisville and Pittsburgh is furnished in a letter, written by Nicholas Simin, Chief Engineer of Water Works, Moscow, Russia, to the editor of *Engineering News* on June 28, 1898. The writer stated that steps were then being taken toward undertaking experiments with different systems of mechanical filters at Moscow. The general arrangement of the experiments was to be similar to that which he had just seen in Louisville and Pittsburgh.

Experiments on Sewage Treatment.—The great advances in sewage treatment which have been made since the growth of cities and industries

forced attention to this problem are associated not only with laboratory research, but also with studies at experimental plants, similar to those mentioned in connection with water purification. These were undertaken chiefly in order to select the most economical method of treatment under the given local conditions. Among the noteworthy studies were the following, which were conducted by, or carried on under the direction of, men who previously had been employed by the Massachusetts State Board of Health: tests on partial purification of sewage by artificial aeration at Brooklyn and Boston, 1910; tests of various methods of treatment at Columbus in 1904 and 1905, and at Cleveland from 1912 to 1914; and tests of various methods of treatment, with especial emphasis on the activated-sludge process, at Milwaukee, beginning in 1914. There can be no doubt that these studies were well worth while in solving local problems, while advancing at the same time the art of sewage treatment and disposal.

Conclusion

From what has been said, it will be seen that the work done in Massachusetts has had an important part in the inception and development in this country of the science and art of public-health engineering, as represented by its two principal branches. Beginning with the establishment of the State Board of Health, and continuing with increased impetus after the advent of the Lawrence Experiment Station, many valuable investigations and researches have been made by engineers, chemists and biologists of the State, covering stream pollution, water purification and sewage treatment. Other Massachusetts engineers and scientists, aside from those in the service of the Commonwealth, have made important contributions toward the development of public-health engineering. A few of the noteworthy Massachusetts names in this field are Ball, Chesbrough, Drown, Fitzgerald, Kirkwood, Lane, Mills, Nichols, Mrs. Ellen H. Richards, Sedgwick, Stearns and Whipple. Among these names, it is well to emphasize those of Sedgwick and Whipple, who, in their classes at the Massachusetts Institute of Technology and at Harvard, have kindled the enthusiasm of hundreds of students in the field of public health. Considering the work done by these and many other Massachusetts engineers and scientists, together with the inspiration which their work has been to engineers throughout the United States, and even abroad, it may be said truly that Massachusetts was the cradle of public-health engineering.

Operation of the Sewage Treatment Plant of the Bloomington and Normal Sanitary District[1]

BY J. J. WOLTMANN[2]

The Sewage Treatment Plant of the Bloomington and Normal Sanitary District consists of bar screens, grit chamber, pumping station, Imhoff tanks, sludge drying beds, sprinkling filters and secondary tank with Dorr clarifier. It was designed for a future population of 54,000. The present tributary population is about 40,000. The two cities are served by combined sewers and an intercepting sewer carries the dry-weather flow and

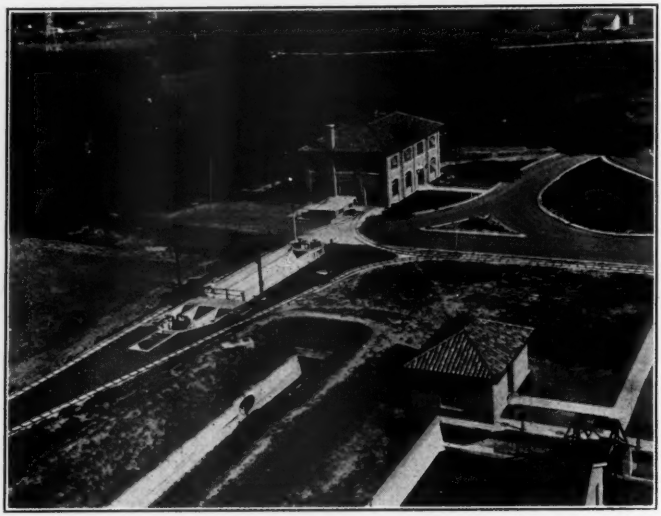


FIG. 1.—Pumping Station and Laboratory, Grit Chamber, Effluent Channel, Sludge-Pumping Station and Corner of Final Settling Tank. Effluent Discharged into Concrete Creek Channel, Covered in Front of Pumping Station. Opening into Channel Is By-Pass, Plant Outlet Is Directly Opposite.

part of the storm flow to the plant. The lower end of the intercepting sewer is of vitrified segment block, 51 inches in diameter and has a capacity of 25 m.g.d. Practically all flows up to 9 m.g.d. are handled through the plant, the remainder being bypassed into Sugar Creek. The sewage is a typical domestic sewage with an average concentration of suspended solids for the past year of 213 parts per million.

[1] *Presented at the Third Annual Meeting of the Central States Sewage Works Association, Springfield, Ill., June 9, 1930.*

[2] *Taylor and Woltmann, Engineers, Bloomington, Ill.*

TABLE I

CONDENSED REPORT FOR THE TWELVE MONTHS ENDING MAY 31, 1930—BLOOMINGTON AND NORMAL SANITARY DISTRICT

	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Average for year 1929–1930
Average Flow, M. G. D.	5.92	5.61	5.53	4.21	4.24	4.79	4.61	4.06	5.94	6.18	6.52	6.02	5.30
Suspended Solids													
Station A	386	134	174	308	246	320	274	106	141.6	139	173.6	157	213
Station B	77	55.3	46.7	57	51	52	54.2	57.7	64.7	59	66.1	69	59
Per cent removal	80	58.7	73.2	81.5	79.2	83.7	80	45.6	54.3	57.6	61.9	56	68
Station C	16	11	2.6	13.5	20	22.9	26	23.7	12.3	12.6	16.2	38	15
Per cent removal	95.8	91.8	92.8	95.6	91.8	92.8	90.5	78.3	91.3	90.0	90.6	76	89
Oxygen Consumed:													
Station A	49.7	26.5	40.3	73.3	55.9	49.3	55.3	40.9	43.7	46.0	46.5	49.7	48
Station B	29.1	12.2	27.6	42.9	35.6	26.4	30.5	32.8	30.2	32.0	31.5	40.1	31
Station C	7.9	1.2	7.5	14	13.8	9.6	10.9	14.6	15.5	11.0	13.4	21.1	12
Free Ammonia:													
Station A	6.1	3.33	5.4	10.2	10.9	10.5	10.8	6.3	4.92	5.5	5.4	9.0	7.3
Station B	7.9	5.26	6.8	15.0	14.4	12.9	13.0	7.4	5.82	6.7	7.1	11.4	9.5
Station C	0.43	0.20	0.53	1.9	2.5	2.6	3.5	2.0	1.47	1.2	0.41	0.48	1.4
Organic Nitrogen:													
Station A	11.2	6.97	8.61	11.3	9.7	10.2	10.7	5.0	7.05	7.9	4.37	5.67	8.2
Station B	7.81	5.21	6.73	6.2	7.6	6.9	7.5	4.7	6.85	6.9	3.70	4.82	6.2
Station C	5.22	2.54	2.72	3.5	3.6	3.9	5.2	2.4	2.42	2.9	2.90	3.20	3.4
Nitrite-Nitrate Nitrogen:													
Station C	7.64	7.64	7.66	7.9	11.0	10.7	8.6	8.0	7.61	9.5	8.2	6.8	8.4
Biochemical Oxygen Demand:													
Station A	93.8	47.2	77.3	164	149	140	138	68	59.6	67.3	47.2	67.4	93
Station B	37.4	19.0	30.9	84	84	57	70.8	40.8	38.1	27.0	20.0	37.7	46
Station C	6.6	2.33	3.8	8.2	19.8	16.7	23.5	23.5	12.7	8.3	7.9	5.96	10.4
Per cent Stabilization	92.9	95.1	95.1	94.9	86.7	88	83	81	86	88.2	91.6	87	89

Station A. Influent
Station B Imhoff Tank Effluent
Station C. Final Effluent. BLOOMINGTON, ILLINOIS.

The plant was placed in operation in June, 1928. (Figures 1 and 2.) During the past year it has handled two billion gallons of sewage or an average flow of 5.5 m. g. d. The daily flows varied from a minimum of about 3.25 m. g. d. to a maximum of 9 m. g. d. During this period the average daily pumpage of the water works of Bloomington and Normal was about 3.25 m. g. d. Analyses of the raw sewage, of the effluent from the primary tanks and of the final effluent are shown in Table I.

The grit chamber has three flow channels, the two outside ones being 4 ft. wide and the center one 6 ft. wide. They are about 65 ft. long. (Figure 3.) Bar screens having one-inch clear openings are placed at the inlet to each

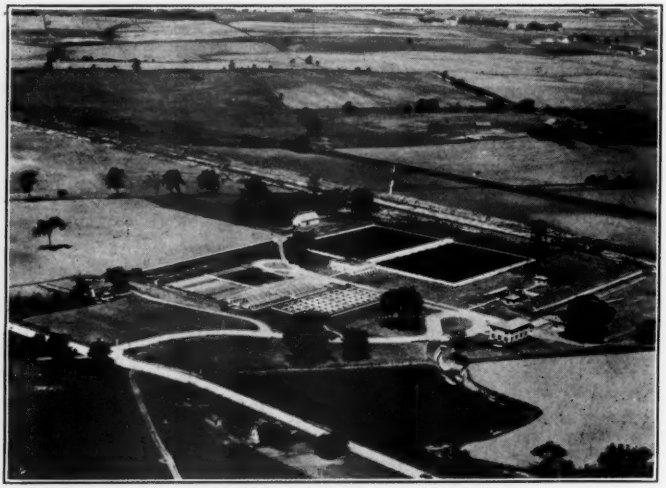


FIG. 2.—Aerial View of Plant. Black Appearance of Surface of Filters Due to Light Filters Used with Aerial Camera.

channel. Grit is shoveled into a bottom dump bucket and then raised by an electric hoist and dumped into a car on the industrial railroad or into a truck. During the past year 541 cu. yd. of grit were removed from the grit chambers. This is an average rate of 0.27 cu. yd. per million gallons. It is thought that the large quantity of grit is due to the use of cinders on streets and yards and possibly some direct discharge from railroad cinder pits. The percentage of removal of grit from the sewage is high. Grit is being used for walks and is also satisfactorily used on the sludge drying beds as a substitute for the finer sand.

It is estimated that more than 5 cu. yd. of rags and garbage are removed from the bar screens each month. This material is raked off the screens and

kept in a covered box during the day and hauled away each morning and covered with grit.

The sewage flows through the coarse bar screens and grit chambers and then to the pumps, which discharge into the Imhoff tanks. Two of the pumps have a capacity of 4 m. g. d. and the third will handle 6 m. g. d. against the usual lift of about 23 feet. (Figure 4.) During the past year 148 kilowatt hours were used per million gallons and the cost of power was approximately $3.00 per million gallons. This includes power for building and grounds lighting, sludge pumping, water pumping and miscellaneous uses.

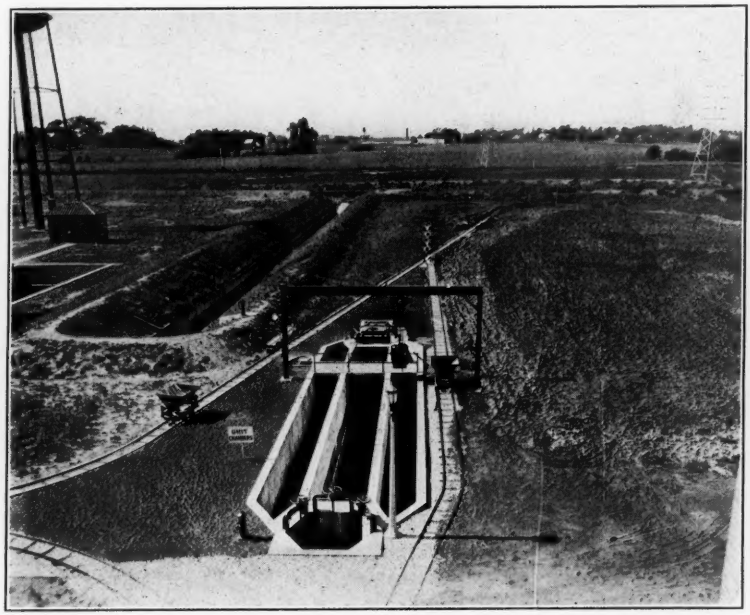


FIG. 3.—Grit Chambers. Side Channels 4 Ft. Wide, Center 6 Ft., Length 65 Ft.

The pumps are horizontal, bronze fitted and of the open impeller type. They are high-efficiency pumps and they are provided with hand holds for quick cleaning. For some time the capacity of the pumps has been decreasing. When opened for inspection recently the side plates were found to be badly worn. In one case the plate was worn entirely through. There may be some wear on the impellers but it is slight. The bronze plates

have been replaced with cast iron ones and capacity brought back almost to the original.

It is thought that the wear has been caused largely by sticks and rubbish catching on the impeller and rubbing against the side plates and by the large amount of light, abrasive cinders carried in the sewage. The pump suctions are along the side of a rectangular-shaped wet well into which the sewage enters at one end. It is interesting to note that the pumps nearest the sewer inlet were worn the most. The pumping station also contains office rooms, laboratory, machine shop and a transformer room.

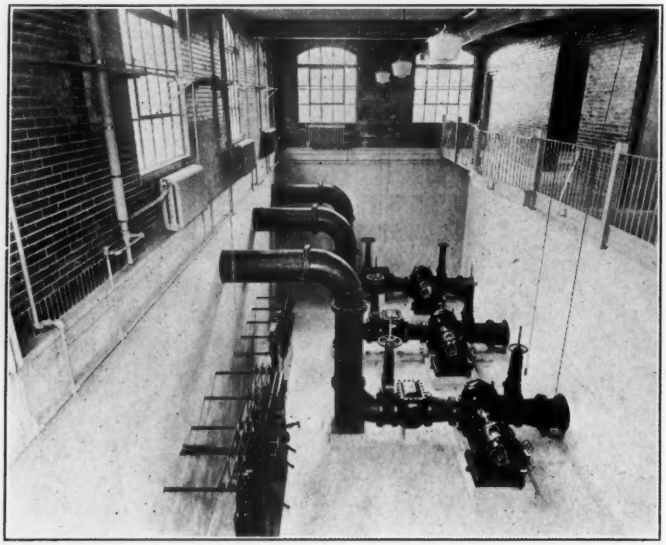


FIG. 4.—Pumping Station. Two 4 M. G. D. and one 6 M. G. D., 23-Ft. Lift.

There are six primary settling tanks of the Imhoff type, placed side by side, with a sludge removal channel between each pair of tanks. (Figure 5.) Each tank has two flowing-through channels. The tanks have a three-hour detention period based on a daily flow of 5.4 million gallons. From the primary tanks the sewage flows through the remainder of the plant by gravity.

The Imhoff tanks have given very little trouble. There has been practically no foaming and the sludge has been of good quality. The tanks are equipped with outlet weirs, operated from stands, making reversal of flow a simple matter; the flow is usually reversed every week, and the flow channels washed out.

In the fall of 1929 the accumulation of oil and grease in the gas vents became quite thick. Hosing down the vents carried some of this into the sludge with the result that the sludge did not dry so readily. This oil and grease has since been pumped from the top of the vents on to several of the drying beds. This has improved the appearance and condition of the vents and has also improved the quality of the sludge. The material placed on the sand beds has not dried satisfactorily and will be hauled away for burial or for use on roads.

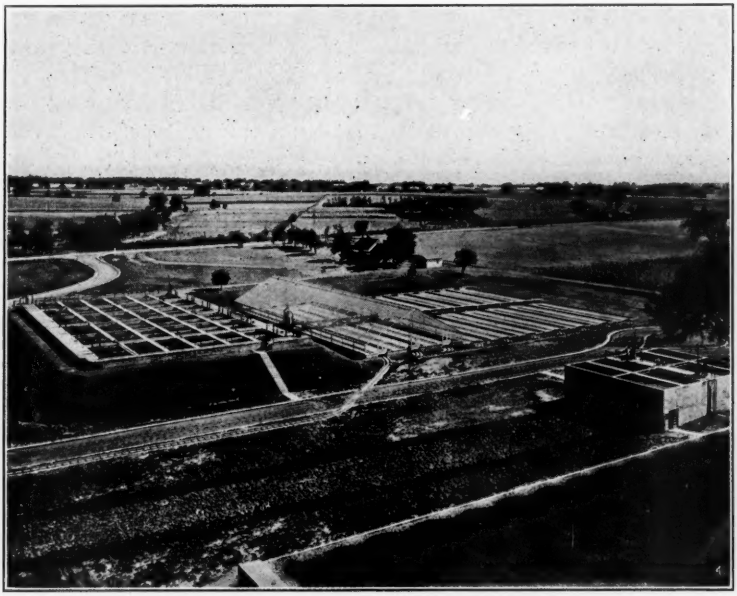


FIG. 5.—View of Imhoff Tanks, Sludge Beds and Dosing Chambers.

The plant was designed so that sludge from the secondary tank would be returned to the center compartments of two of the primary tanks. This sludge did not settle readily and seemed to cause an inferior sludge in these tanks. It is now returned to the incoming sewage in the wet well and goes to all of the tanks. This has been a more satisfactory arrangement.

During the past year 3720 cu. yd. of dried sludge have been removed from the beds. This is at the rate of 1.86 cu. yd. per million gallons or 0.093 cu. yd. per person based on a population of 40,000. About 300 cu. yd. were hauled away for fertilizer and the remainder was used to fill in low places. Six of the twenty drying beds are glass covered. There are

41,800 sq. ft. of drying beds, including both the covered and open beds. This is equal to 0.774 sq. ft. per capita on the design basis of 54,000 persons or 1.04 sq. ft. per capita for the present population.

The glass-covered drying beds are in use most of the time except during the summer months, when it is very hot under the glass. The men prefer the open beds in the summer. For this reason it is not possible to compare the sludge output from the open and covered beds.

The sludge storage volume in the Imhoff tanks up to a point 18 in. below the slots is 156,420 cubic feet. This is 2.9 cu. ft. per person on the design basis of 3.9 cu. ft. per person for the present population. The sludge removed during the year was 100,440 cu. ft. or 2.51 cu. ft. per person, measured dry.

There are two twin dosing tanks, each pair discharging onto one-half of the filter area. The 30 in. siphons are of the trapless type. Air-release valves were placed in each main discharge line just ahead of the first row of nozzles. They operate satisfactorily in releasing air, which otherwise would interfere with nozzle discharge. The tanks were built open at the top and have been covered with plank in the winter. At the present time a frame housing is being built over the tanks for a permanent covering.

The filter beds have a gross area of 2.5 acres. A covered gallery between the beds houses the main cast-iron distribution lines and the main discharge channels. The filter beds have operated satisfactorily. Clogging of nozzles has not been a serious matter as screens placed in the effluent channel of the primary tanks catch matches and other objects which tend to clog the nozzles. There has been some breaking up of stone at the surface of the beds and some disintegration of concrete at the tops of walls which are alternately wet and dry. It is planned to give these walls a protective coat of asphalt paint. Occasional flooding of the beds has reduced the number of flies so that they have not been a nuisance.

In the summer of 1929 there was some pooling on the beds but this stopped following the use of chloride of lime. It is the practice now to apply about 5 p. p. m. for one day each week, the application being made at intervals of 2 hours. It is added in the dosing tanks, at the time when they are beginning to fill. Sloughing of the filters has occurred to the greatest extent in the latter part of May and in October.

The secondary tank is 70 ft. square and equipped with Dorr clarifier mechanism. The sludge pump is operated for about 3 hours each day. The sludge is pumped to the wet well where it is mixed with the incoming sewage.

The operating force consists of the superintendent, chemist and 5 men during the entire year and usually 2 additional men during the summer months. The chemist is on a part-time basis. The pump men operate on 8-hour shifts, the others work 9 hours. The plant force also takes

care of the intercepting sewers and several miles of open ditch right of way owned by the District. The grounds are large and well landscaped and considerable labor is used keeping the grounds and drives in good condition. The plant has an inviting appearance and visitors are numerous.

The total plant operating cost for the past year was approximately $21,000. For a sewage flow of 2 billion gallons this cost equals $10.50 per million gallons. This includes the salaries of the superintendent and chemist and also includes the cost of maintaining the intercepting sewers and the open ditch right of way.

The distribution of this cost is approximately as follows.

Power and light	$ 3.00
Sludge handling	1.50
Care of grounds	1.50
Laboratory	1.00
Primary tanks	.50
Secondary tanks	.50
Supplies	.50
Pumping and miscellaneous	2.00
Total, per million gallons	$10.50

The cost of handling grit and sludge has been reduced recently by the use of a truck instead of the cars on the industrial track. The cost of moving the track and of spreading is largely saved by the truck.

The writer wishes to express his thanks to Mr. H. E. Wilson, Superintendent, who so kindly furnished the operating data and other information for this paper, and to Mr. Howard Adams, Chemist, for the analyses shown in Table I.

Preliminary Studies on Causes and Remedies for Mosquito Breeding in Sewage Disposal Plants[1]

BY JOSEPH M. GINSBURG, PH.D.,[2] AND LEROY FORMAN[3]

A modern sewage-disposal plant, well constructed and efficiently operated, should offer few opportunities for mosquito breeding. Only poorly constructed or inefficiently operated plants, where the effluent is not properly drained off, allowing pools of water to accumulate on the filter beds or adjoining areas sufficiently long for mosquitoes to develop, create temporary or permanent breeding places and become a serious nuisance to the community. In most instances these breeding places could be readily eliminated by efficient operation, except where the capacity of the plant is not large enough to take care of the amount of sewage received daily. Under such conditions petroleum oils or larvicides must be applied, but only as temporary remedies.

The effect of mosquito oils and larvicides on the biological and chemical activities in the effluents from the sewage treatment plant, or upon the sewage decomposition taking place in the sedimentation tanks, has always been a debatable question among sewage-plant operators and mosquito-control workers. The effluent from sedimentation tanks still contains putrescible organic matter in suspension and solution. The transformation of these materials into stable compounds that will not exceed in their demand for oxygen the supply provided in the water courses into which they are discharged, is accomplished chiefly by oxidation and filtration, in which biochemical processes play a significant part. A study was therefore made of the immediate and residual effects of several oils and larvicides, generally used in mosquito-control work, on the bacteriological and biochemical activities in sewage disposal. A study was also made of the causes responsible for mosquito breeding in sewage plants and possible permanent remedies. The investigation is conducted jointly by the Agricultural Experiment Station and the State Department of Health, upon the request of the New Jersey Mosquito Extermination Association.

While the problem is still under investigation the authors feel that a brief preliminary report of the results obtained thus far may prove of immediate benefit to the operators of sewage-disposal plants and mosquito-control workers. A full report of the bacterioloical and chemical analyses will be published upon the completion of these studies.

[1] *Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Entomology.*

[2] *Biochemist in Entomology, New Jersey Agricultural Experiment Station.*

[3] *Senior Chemist, State Department of Health.*

Experimental

Application of Oils and Larvicides.—The preparation, testing and application of the oils and larvicides was carried out by the senior author, while the collections of samples of effluent, and bacteriological and chemical analyses were conducted by the junior author.

Of the various types of sewage-disposal plants in operation in New Jersey the most common are sprinkling-filter and intermittent sand-filter types. Accordingly, three plants of the first type and two of the second were selected for this investigation.

Four grades of petroleum distillates (generally employed in mosquito control work in New Jersey) of various boiling ranges and volatilities were selected. Every one of these oils has been previously tested against larvae and pupae of *C. pipiens*, both in the laboratory and in the field, and were found toxic to both stages. The specifications and toxicities of the oils are given in Table I.

TABLE I

SPECIFICATIONS AND TOXICITY OF THE FOUR OILS TESTED

Kind of Oil	Boiling Range ° F.	Viscosity Saybolt/ 100	Volatility in 48 Hrs. at 75° F. %	Baumé Gravity	Flash Point ° F.	Time to Kill 100% Larvae and Pupae When 24 Gal. per Acre Are Used
Varnolene.....	300–417	..	94	46	96	15 minutes
Mosquito oil No. 205	360–730	38	40	33	150	30 minutes
Furnace oil No. 1...	430–630	35	22	34	170	1 hour
Furnace oil No. 2...	364–723	56	35	29	156	1 hour

Two kinds of larvicides were used. One consisted of cresylic acid incorporated in Mosquito Oil No. 205, in various proportions. Cresylic acid and similar coal-tar products are frequently used by mosquito workers to increase the spreading properties and toxicity of the oil. The second larvicide consisted of extracts of pyrethrum (ground flower-heads of *Pyrethrum cinerariafolium*). It was applied in two ways. In the first case an alcoholic extract of pyrethrum, 1 cc. of which was equivalent to 1 gm. of flowers, was applied at the rate of 3 cc. to each cubic foot of water. This was equivalent to approximately one part of flowers in 10,000 parts water. The extract is miscible and is rapidly dispersed throughout the volume of water. Half of the above concentration, namely, 1:20,000, was found adequate to kill larvae and pupae when tested both in the laboratory and the field. In the second case a kerosene extract was used (one pound of pyrethrum flowers to one gallon of kerosene), emulsified with potassium oleate or similar soaps. The resultant emulsion consisted of 66 per cent kerosene containing the extract, 32 per cent water, and about 2 per cent soap. The emulsion was diluted 1:10 with water before application. In this preparation the pyrethrum extract is insoluble in water

and comes up to the surface in the form of a thin layer, held by the kerosene. Under these conditions the concentration of pyrethrum necessary to kill larvae and pupae is based on the surface area regardless of the depth of the water. This larvicide has been tested out on different mosquito-breeding places and was found to be efficient in killing larvae and pupae at a cost lower or equal to that of furnace oil; it therefore has a practical application.

The composition and toxicity of the larvicides are given in Table II. The alcoholic extract was applied on one filter bed at the Metuchen plant. The area of the bed was approximately one-fifth of an acre, while the depth of the effluent at the time of application was about 4 inches. The concentrated alcoholic pyrethrum extract was mixed 1:4 with water to facilitate spraying and enough of it was applied to obtain the desired (1:10,000) dilution. The kerosene pyrethrum extract was applied on one sprinkling filter at the Haddonfield plant.

TABLE II

COMPOSITION AND TOXICITY OF THE LARVICIDES

Larvicide No.	Chemicals Per Cent	Oil Per Cent	Dilution	Time to Kill 100% Larvae and Pupae
1	Cresylic acid 1.5	98.5	.....	30 minutes
2	Cresylic acid 5.0	95.0	.....	15 minutes
3	Cresylic acid 10.0	90.0	.....	15 minutes
4	Pyrethrum alcoholic extract	None	1:10,000 gms. of flowers	2 hours or less
5	Pyrethrum kerosene emulsion	6.6	1:10 dilution	2 hours or less

The oils and larvicides were applied from either bucket pump or knapsack sprayers, the spraying being done by experienced oilers from the various mosquito-control commissions in close proximity to the sewage plants. Both filter beds and sedimentation tanks (if the latter were open and accessible for spraying) were sprayed.

Methods of Testing the Effluent.—Just before the various sprays were applied a two-hour composite sample was collected from the tank effluent and sprinkling-filter or sand-filter effluent, compositing every fifteen minutes. After the larvicides were sprayed upon the filters a similar composite sample of the secondary unit was obtained and also catch samples at each interval of compositing for the determination of nitrites and nitrates. The following tests were made on the composite samples: *B. Coli*, in brilliant green media; dissolved oxygen; biochemical oxygen demand; total solids; suspended solids; total nitrogen; organic nitrogen; nitrite nitrogen; nitrate nitrogen; oxygen consumed; phenols (where cresylic acid was used); 37° bacteria on agar.

On three occasions a member of the Department of Health revisited a plant after a lapse of five to ten days and samples were again collected.

The purpose of this procedure was to determine any possible residual effects of the larvicide in the normal functioning of the plant.

Results

The chemical and bacteriological analyses brought out the following points:

1. Neither the light oil such as varnolene, nor the heavier oils such as Mosquito Oil No. 205, nor furnace oils interfered in any way with the bacteriological and biochemical activity of the sewage. The same results were obtained with the two larvicides containing pyrethrum.

2. Oil containing 5 per cent cresylic acid slightly decreased the number of bacteria in the effluent and increased somewhat the total and suspended solids, indicating a general slowing down of the nitrification processes of the sewage.

3. Oil containing 10 per cent or more cresylic acid showed a decided effect upon the bacteriological and biological activities. The bacteria were reduced about 80 per cent, while the B. O. D. increased about 100 per cent. Total and suspended solids, oxygen consumed and organic nitrogen showed increases, while the nitrification processes almost completely ceased. A revisit was made to plants where the cresylic acid oil spray was used after a lapse of 10 days and it was found that the normal functions of the filter had been restored.

4. The effect of oil containing 1.5 per cent cresylic acid, or only enough to spread the oil, did not indicate any material changes in the results of the composite sample. One of the catch samples, however, namely, the second discharge, collected about 25 minutes after application of larvicide, showed incomplete oxidation as was indicated by very high nitrite and no nitrate.

Discussion

From the results obtained, and from observations made by the writers during the course of the investigation, it became clear that the oils commonly used in mosquito-control work can be safely applied on sewage disposal plants without in any way interfering with the chemical and bacteriological activities in sewage disposal. Attention should be drawn, however, to the possible deleterious effects of heavy oils such as heavy fuel oils, residue oils, and heavy lubricating oils, which may remain in the filter beds for a considerably longer time to interfere with filtration and aeration processes. Furthermore, these heavy oils are rather low in toxicity to larvae and pupae. For these two reasons, the application of the heavy oils, mentioned above, may well be eliminated from sewage disposal plants.

TABLE III

CAUSES AND REMEDIES FOR MOSQUITO BREEDING

Mosquito Breeding Observed	Causes	Remedies
1. Surface of Imhoff tank due to quiescent state of liquid	Improper baffling	*a* Reverse flow *b* Proper baffling
2. In channels and flowing through compartments of one-story settling tanks	Improper baffling and dead areas	*a* If housed, properly screen building *b* If not housed, covering tank close to flow line
3. Gelatinous mass at high liquid level in siphon chamber	Natural gumming of sewage	Cover siphon chamber with fine mesh screens
4. Wet ground adjacent to sprinkling filter beds	*a* Discharge of spray from sprinkling filter nozzles produced by full nozzles at edge of filters or by winds *b* Improper drainage of these areas *c* Loose wall construction of sprinkling filters	*a* Half nozzles *b* Housing of sprinkling filter under glass *c* Increase end zones of filter *d* Proper drainage of areas adjacent to sprinkling filters
5. In material filters as in broad-irrigation method of sewage disposal	Gradual clogging by suspended material and organic matter	Abolish the natural filters
6. Lagoons receiving supernatant liquid from separate sludge digestion tanks	Ponding	*a* Rapid filtration and drainage *b* Abolish the lagoon
7. Pools adjacent to sand filters and sprinkling filter beds	Insufficient grade of under drains in sprinkling filters and sand filters to produce proper drainage to main outfall channels from such devices	*a* Properly graded underdrains *b* Drainage of ground adjacent to filter beds
8. Open detention tank	Quiet surface on open tank	Covering of tank
9. Pooling and stagnation of final effluent in ditch leading to the receiving waters	*a* Improper drainage *b* Heavy growth of vegetation in ditch *c* Not sufficient fall	*a* Keep ditch free from dense vegetation growths *b* Have proper drainage of these areas and sufficient fall

Our observations throughout this study suggest the following causes and possible permanent remedies for mosquito breeding in sewage disposal plants (Table III).

Recommendations to the Sewage Plant Operator

Particular attention by the sewage plant operator to the following phases of operation will greatly reduce or completely eliminate his plant as a potential mosquito-breeding place:

1. Reverse the flow in the tanks at least once a week.
2. Break up sludge in gas vents daily.
3. Remove slimy formation at the liquid level in the siphon chamber.
4. Do not allow pooling to occur on the sprinkling filter.
5. Do not allow pooling and clogging to occur on the sand beds.
6. Do not throw scum, grease and slime on open ground.
7. Do not allow sludge to remain on open drying beds any longer than necessary.
8. Do not allow wet areas to remain around the sprinkling or sand filters.
9. When no immediate relief can be secured by the above methods the breeding areas should be sprayed with oil.
10. The oil should be sprayed at weekly intervals during the mosquito-breeding season (if continuous breeding prevails) at the rate of about 50 gallons per acre area.

Summary and Conclusions

Preliminary experiments with various petroleum oil distillates and larvicides were conducted with the purpose of studying their effect on the bacteriological and biochemical processes when sprayed on filter beds and sedimentation tanks to control mosquito breeding. Five disposal plants of both the sprinkling-filter and intermittent-sand-bed-filter types were used for this investigation. Chemical and bacteriological analyses of the effluents were made before and after treatment. A study was also made of the various causes responsible for mosquito breeding in sewage plants and their permanent remedies. The results obtained and observations made suggest the following tentative conclusions:

1. Most of the breeding places encountered in sewage disposal plants can be permanently eliminated by proper mechanical methods.
2. Where permanent elimination of breeding places is not possible, application of the following oils is recommended in order to obtain rapid and complete kill (*a*) furnace oil, (*b*) light fuel oil, and (*c*) kerosene.
3. The following oils should not be used at all, or only to a limited extent, because they may leave oil or tar residues on the sand beds and to a lesser extent on the sprinkling-filter beds, which might interfere with the

proper filtration and bacteriological activities: (*a*) residue fuel oils, (*b*) flux oils, and (*c*) heavy lubricating oils.

4. None of the oils tested exerted any detrimental effect on the bacteriological and biochemical activities in sewage disposal.

5. Oils containing 5 per cent or more cresylic acid caused a temporary reduction in the oxidation processes of the sewage filter beds. The normal functions of the beds were restored within five days or less.

6. Oils containing 1.5 per cent cresylic acid only slightly, if any, affected the normal activities of the filter beds.

7. Neither of the two pyrethrum larvicides, in the dilutions here tested, showed any influence whatsoever upon the bacteriological and biochemical activities of the sewage.

Acknowledgment

The authors feel indebted to Dr. T. J. Headlee, State Entomologist, to Mr. H. P. Croft, Chief Engineer, State Department of Health, and to Dr. W. Rudolfs, Professor of Water Supplies and Sewage Disposal, for valuable advice.

Mosquitoes.—A brief résumé of the various measures applicable for mosquito eradication has been given by V. M. Ehlers. Breeding places should be located and the types and prevalence of mosquitoes noted. The measures to be applied include ditching, filling, clearing streams, dusting, oiling and propagation of minnows.

Drainage is most effective, but frequently quite expensive. A larvicide composed of one part of black oil and three parts of kerosene is generally used. One gallon will cover 1000 sq. ft. of water surface. The oil should be applied at weekly intervals. Dusting with paris green and lime has been found fairly effective in controlling breeding of the malaria carriers. The paris green should contain not less than 50 per cent arsenious oxide and should pass a 300-mesh sieve. Top minnows are of value in destroying mosquito larvae. Birds and bats are of doubtful value.

A mosquito-eradication campaign should include passage of an ordinance, adoption of a budget, appointment of a director and planning of the use of the various methods that have been found to be effective. A general civic clean-up campaign, proper screening of garbage, free drainage of culverts and storm sewers and an educational program are essential.—V. M. EHLERS. *Municipal Sanitation*, **1**, 315, June, 1930.

The Sewage Treatment Works of Zurich, Switzerland

BY MAX SUTER*

Zurich, with 230,000 inhabitants, the largest city of Switzerland, had until about ten years ago a sewerage system of the combined type, aided by screening buckets in all houses to reduce solids in the conduits. This system was planned to discharge dilute storm-water sewage over many overflow weirs into the Limmat, the river flowing through the city. These sewers became overloaded as Zurich grew, resulting in the construction of a separate sanitary-sewer system, retaining part of the old system for storm sewers and part for the new. A complete separation was not attained, since only the new buildings were forced to connect to the new system, consequently some storm water had to be carried by it. Even under these conditions 65 per cent of all houses were connected to the sanitary sewer four years after their installation.

Partial cleaning of the sanitary sewage was required before final discharge into the Limmat River. It was first thought that the elimination of 75 per cent of the settleable solids would be sufficient, but now an efficiency of 95 per cent is desired.

The average dry-weather flow is about 40 M. G. D., of which only 20 M. G. D. is house sewage (daily flow per capita 65 gal.), 10 M. G. D. is industrial sewage and 10 M. G. D. is clear water from creeks and infiltration. To this may come 60 M. G. D. rain water.

The disposal plant consists of rain-water overflow weir, grit chamber, 2-in. bar screen, sedimentation chambers, pumps for sludge, separate sludge-digestion chambers, sludge-drying beds and lagoons.

As it was expected that the sanitary sewer system might come slowly into use, a plant for only about one-third of the population was first built from which experience could be gained for the design of the complete works. This first plant was finished in 1926 and the full plant is under construction in 1930. It will have only slight changes from the original layout.

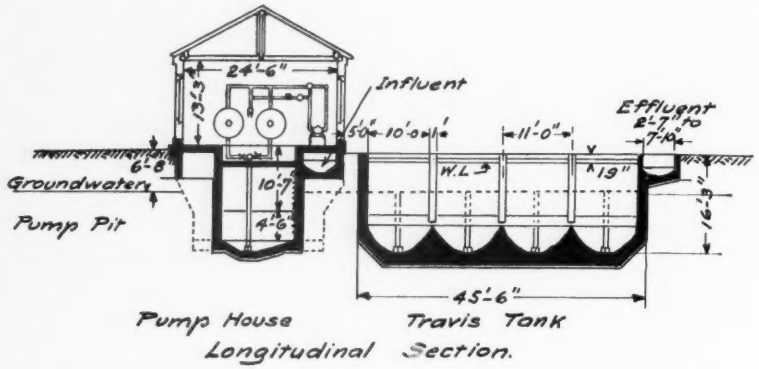
Grit Chambers.—The grit chambers consist of three channels, one, two or three of which are used depending on the volume of flow. A velocity of 1.0 to 1.5 ft. per second is maintained, but even with these velocities organic matter is deposited in the channels with the grit, although at different places in the channels, so that these materials can be fairly well separated when the grit chambers are cleaned.

Sedimentation Basins.—As the plant lies in a flat, gravel-filled valley with a high ground-water level, deep excavation had to be avoided. For this reason separate sludge-digestion was preferred, with gravity flow of sewage and pumpage of sludge.

The sedimentation basins are built as modified Travis tanks resembling

* *Consulting Engineer, 664 So. West St., Jacksonville, Illinois.*

Imhoff tanks, but with some flow of sewage through the center channel and with the bottom subdivided into four small round hoppers from which sludge must be drawn daily.



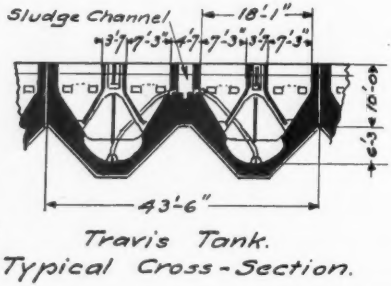


FIG. 1.—Pump House and Settling Tanks, Zurich.

The efficiency of the sedimentation chamber is high; with a retention period of only twenty minutes, 80 per cent of the settleable solids are removed. This permits treatment of the entire flow in the present small plant. After the new addition is finished the retention period will be forty-five minutes, which should accomplish 95 per cent removal of settleable solids from the sewage. The Zurich sewage has about 2500 parts per million settleable sludge (2.5 cc. in Imhoff cone). Floating particles and oil and fats collecting on the surface of the sedimentation chamber are retained by a baffle wall and occasionally skimmed. The effluent of the sedimentation tanks is conducted into the Limmat through a 28-in. iron

pipe, discharging at a point about thirty feet in the river from the bank at low water.

Pumping Station.—The sludge from the six present and the future chambers is collected by gravity flow at the sump pit of the pumping station. The pumping unit consists of two iron tanks of about 180 cu. ft. capacity, into which the sludge is drawn and expelled by an electrically-driven compressor put into operation by a floating switch. Sludge can be pumped to the digestion tanks directly, to their preliminary decantation tanks or to an independent outlet.

Separate Sludge Digestion.—The sludge can be pumped to high-level filling tanks of about 1600 cu. ft. capacity, where after a few hours of settling much of the water can be drained off before the sludge is brought to the digestion tanks. This decantation is now seldom used as the wet sludge seems to allow better mixing of old and new sludge and better digestion. The sludge-digestion chambers have a capacity of 1.24 cu. ft. per capita, which seems from the present experience to be ample.

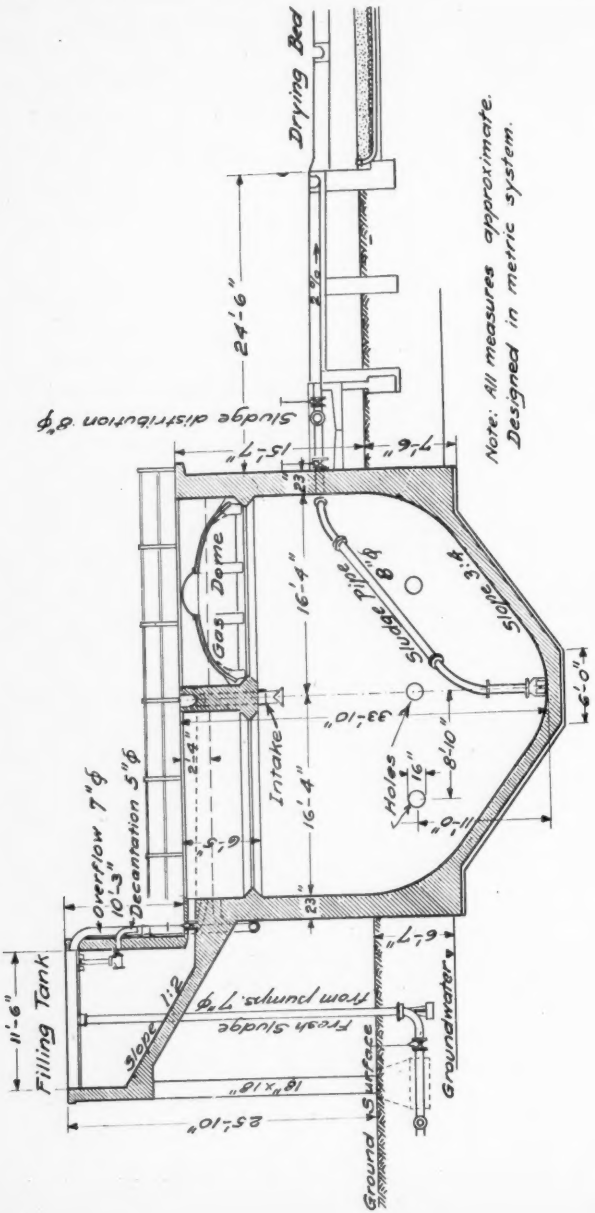
There are now six digestion tanks each of about 20,000 cu. ft. capacity. (Figure 2.) The tanks are interconnected in groups of two and each group of two has its filling tank.

In order to get good mixing of old and new sludge, the sludge is introduced from above in the center of the tank. By filling or draining only one tank at a time, the sludge moves from one tank into the other through the interconnecting holes; this circulation helps to mix the sludge.

One chamber is covered with a gas-collecting dome for experimental purposes. The gas production in this chamber is very little in winter; it increases to 3500 cubic feet per day in spring and to 10,000 cubic feet per day in summer. The gas contains about 70 per cent methane and 30 per cent carbon dioxide. It has a heating value of 715 B. t. u. per cubic foot. No use is made of the gas at present. Gas collection was accomplished without much difficulty for the first three years, then suddenly scum formed and hardened, caused clogging of the gas lines and even lifted one of the gas-collecting domes.

Digested sludge is dried on drying beds, of which there are 32,000 square feet. This is not sufficient in winter. Successful results have been obtained in the lagooning of ripened sludge. For this procedure digested sludge is discharged in layers of four to six inches on a bed, without underdrains, enclosed by earthen dams, until a depth of nearly four feet is reached. Then a dam is opened and the sludge sold to farmers. First it was given away, but after the manurial value was recognized it sold for about thirty-one cents per cubic yard.

New Plant.—As previously stated, additions to the original plant are at present under construction. In this new plant the following main



Cross-Section of Digestion Chamber.

FIG. 2.—Separate Digestion Tanks, Zurich.

changes from the old plant have been made, in addition to the longer retention period for sedimentation:

1. Mechanical cleaning of grit chamber.
2. Steeper slopes in fresh-sludge collecting hoppers.
3. Better separation of fats and oils.
4. Submerging pumps to avoid suction lift, which sometimes gives trouble.
5. Larger sludge-digestion units, each 48 ft. square, 31 ft. total depth and with about 54,000 cu. ft. capacity.
6. Each digestion tank contains four hoppers.
7. Elimination of filling tanks for decantation.
8. Insulation for digestion tanks by earth fills.
9. Heating of sludge through introduction of clean water at 176° F.
10. Complete collection of all gas.
11. Scum protection by means of wooden screens under the gas-collecting dome and lateral pipes to carry away the scum.
12. Abandoning of expensive sludge beds in favor of lagooning ripened sludge.

Cost.—The cost of the first plant was about $280,000 and the cost of the present extension is estimated to be $460,000, which amounts to an outlay of $2.46 per capita, or $1860 per M. G. D. Yearly operating costs are about $8000.

Use of Sewage Gas as City Gas[1]

BY W. H. FULWEILER[2]

In discussing a new source of gaseous fuel for use as city gas there are three important factors to be given consideration, *viz.:* (*a*) the chemical composition, (*b*) the volume and dependability of supply, (*c*) the cost.

Chemical Composition.—In Table I are given a number of analyses of gas as produced by both Imhoff and separate digestion tanks in different plants.

TABLE I

ANALYSES OF SEWAGE GAS

City	Type	CO	H_2	CH_4	CO_2	O_2	N_2	B. T. U.
Decatur, Ill.	Imhoff			69.0	16.8	0.1	14.1	690
Calumet, Chicago, Ill.	Imhoff			76.6	14.7	0.5	8.2	780
Stuttgart, Germany	Imhoff		4.7	75.5	14.0		4.7	770
Milwaukee, Wis.	Digestion	0.6		67.5	30.0	0.2	1.7	677
Halle, Germany	Digestion			72.9	24.0	0.6	1.6	729
Birmingham, England	Digestion			77.0	18.1	0.4	3.2	700
Baltimore, Md.	Digestion			70.5	26.5	0.2	2.8	707

These gases contain from 65 to 80 per cent methane and 14 to 30 per cent carbon dioxide, with relatively small amounts of other constituents. In general, we should not expect any appreciable amount of hydrogen, consequently the heating value of the gas is due almost entirely to the methane. Under these conditions we might expect that the heating value would vary between 650 and 800 B. t. u. per cu. ft.

When we compared such a gas with the several types of city gas now in use, we found that they had quite different compositions. Table II gives the chemical composition of coke oven gas, carburetted water gas, reformed still gas and an average sewage gas, also that of an average sewage gas mixed with blue water gas in the proportion of approximately 52:48.

TABLE II

	Coke Oven	Carburetted Water Gas	Reformed Oil Gas	Sewage Gas	Sewage Gas plus Blue Gas
Illuminants	2.9	9.8	3.6	....	....
CO	7.3	29.5	18.2	....	18.2
H_2	50.9	37.6	52.1	....	24.0
CH_4	29.2	11.4	16.7	75.0	39.1
C_2H_6	0.0	0.7	....	....	....
CO_2	2.8	5.9	4.0	20.0	13.0
$O_2 + N_2$	6.9	5.1	5.4	5.0	5.5
Heating value B. t. u.	541	538	520	750	530
Specific gravity	0.44	0.69	0.47	0.77	0.66

[1] *Presented before the Fourth Annual Conference of The Pennsylvania Sewage Works Association, State College, June 27, 1930.*

[2] *Chemical Engineer, The United Gas Improvement Co., Philadelphia.*

One of the important differences that will be noted from this table is the fact that while other city gases contain from 30 to 50 per cent hydrogen, there is little, if any, hydrogen in the sewage gas.

Effect of Composition on Use.—When we consider the composition of city gas as affecting its usefulness there are three important factors: the heating value, the burning characteristics and the specific gravity.

Experience in this section of the United States with the usual methods of production indicate that a heating value of about 530 B. t. u. per cu. ft. will enable the utilities to give the customer the greatest amount of service at the least cost. It is evident then that the sewage gas is considerably higher in heating value than required and could serve as an enricher for a gas of lower heating value. From this point of view, the gas is satisfactory.

The burning characteristics, however, are not so favorable. A gas flame may be considered as a standing explosion. In other words, the gas is caused to issue from the burner tip at a rate sufficiently in excess of the speed of flame propagation so that the flame will continue to burn on the burner and not flash back.

Now the speed of flame propagation of the three important constituents in city gas varies quite widely. Burning in air, hydrogen would have a velocity of about 16 feet out per second; carbon monoxide a velocity of 5.9 feet per second and methane about 3.9 feet per second, so that the ordinary gases containing considerable amounts of hydrogen will have a very high rate of flame propagation as compared with gases containing largely methane. Furthermore, in the sewage gas we have a relatively large amount of carbon dioxide which would further decrease the rate of flame propagation. As a result, the ordinary appliances as installed would not be suitable for burning this mixture as the orifices would be too small and would cause the flame to blow away from the burners due to the fact that they are adjusted for much faster burning mixtures. The burners would have to be replaced with the type used for natural gas.

Due to the high heating value of sewage gas it could be used to enrich blue water gas to the usual value of 530 B. t. u. If this was done it would require a mixture of approximately 52 per cent sewage gas and 48 per cent blue water gas. The composition of such a mixture is given in Table II. This mixture would contain some 24 per cent of hydrogen and could be used satisfactorily in the present appliances.

The specific gravity of the gas is a factor that affects the distribution of gas through the main system. It will be noted in Table II that the specific gravity of the sewage gas is 0.77, relatively very high. This would increase the cost of pumping it from the disposal plant to the gas plant and would reduce the capacity of the distribution system. For example, if we had to discharge 20,000 cu. ft. per hour through a 4-in.

main five miles long the initial pressure required for sewage gas would be 40 lb. while the initial pressure with the coke oven gas would be 19 lb., and the power required would be 40 H. P. as against 24.

All these points become important when it is realized that the gas would probably have to be pumped a considerable distance from the sewage disposal plant to the gas plant.

We may summarize the above discussion by pointing out that the sewage gas, although it has a sufficiently high heating value to be useful, has undesirable flame characteristics and a high specific gravity in consequence of which it would require a greater expenditure of power for pumping; furthermore the flame characteristics would be greatly improved if the sewage gas were mixed with some other type of gas to increase the hydrogen content.

Amount of Gas Available and the Continuity of Supply.—A very important factor in the consideration of any source of gas for use in augmenting the supply of city gas is the continuity and dependability of supply. The public utilities have made very large investments in duplicate generating apparatus and facilities of all kinds to insure against any possible accident that might cut off the supply of city gas. For this reason it is necessary to inquire carefully into the source of supply, or to make investment in reserve apparatus which must be maintained in operating condition to guard against failure.

TABLE III

GAS PRODUCTION FROM DIGESTION TANKS

Unheated Tanks	Population	Gas per Million Gal. of Sewage	Cu. Ft. of Gas per Capita per Day
Charlotte, N. C.	50,000	2360	0.18
Essen Rellinghausen	45,000	1640	0.21
Stuttgart, Germany	350,000	4350	0.29
Münich, Germany	500,000		0.35
Calumet, Chicago, Ill.	4,400	1373	0.44
Heated Tanks			
Essen Frohnhausen, Germany	33,000	2570	0.41
Antigo, Wis.	5,600	6200	0.66

It is believed that we can assume that any well-managed sewage disposal works would be dependable as a source of supply. However, consideration would have to be given to the fact that frequently sewage disposal plants are located adjacent to streams which might be subject to flood conditions.

The small amount of gas available from a sewage disposal plant would seem to be the greatest disadvantage in considering its use for supplementing the city gas supply. In Table III is given the production per capita per day of a number of plants. It may be noted that this varies from 0.18 cu. ft. to as high as 0.66 cu. ft. per capita per day. The general

assumption has been that under normal operating conditions we might expect to secure about 0.35 cu. ft. per capita per day or, say, 130 cu. ft. per year.

In this connection it might be of interest to calculate the theoretical amount of gas that can be obtained in the form of methane and carbon dioxide from a sewage yielding 60 tons of sludge per year per 1000 inhabitants, assuming that the sludge contains 30 per cent carbon and 3.9 per cent hydrogen. These conditions would be equivalent to about 329 lb. of sludge per day per 1000, containing 12.82 lb. of hydrogen and 98.7 lbs. of carbon.

We assume that the gas will contain 75 per cent of CH_4 and 20 per cent of CO_2. One cubic foot would therefore require 0.04924 lb. of carbon and 0.00795 lb. of hydrogen or a ratio of 1 to 6.2 whereas in the sludge we have a ratio of 1 to 7, so that the hydrogen is the determining factor, and the 12.82 lb. of hydrogen would produce theoretically 1610 cu. ft. of gas or at the rate of 1.6 cu. ft. per capita.

It is evident from Table VII that from a gasification standpoint even under the most favorable conditions, less than 30 per cent of the theoretical yield is secured. We may compare this with the city gas required. Table IV shows the production of sewage gas and the amount of city gas from several cities and in Table V is given the city gas used per inhabitant for a number of Pennsylvania cities.

TABLE IV

COMPARISON OF SEWAGE GAS PRODUCTION AND CITY GAS USED

Place	Population	Sewage Gas per Year	B. T. U.	City Gas	B. T. U.
Charlotte, N. C.	40,000	3,300,000	730	304,443,000	556
Antigo, Wis.	5,600	1,300,000	700	17,000,000	520
Birmingham, Eng.	920,000	44,000,000	630	14,340,000,000	475
Essen District, Ger.	67,000	27,350,000	700	3,810,000,000	470
Münich, Germany	500,000	61,000,000	700	2,118,640,000	475
Stuttgart, Germany	350,000	37,000,000	755	1,470,000,000	475

TABLE V

CITY GAS CONSUMED PER CAPITA PER YEAR

Allentown	5300 cu. ft.
Chester	9800 cu. ft.
Harrisburg	7400 cu. ft.
Philadelphia	9800 cu. ft.
Reading	8400 cu. ft.

From these tables it is evident that the amount of sewage gas produced in a given locality will rarely exceed 1 per cent of the city gas required in the same locality. Under these conditions sewage gas could never expect to make any important contribution to the supply, or in other

words it would not permit of any saving of investment or operating labor in the plant.

Another limitation is the fact that in this latitude the maximum production of sewage gas occurs during the summer months and the minimum production in winter, while the consumption of city gas is just the reverse.

In one large plant in this State each month's consumption during December, January and February is approximately 10 per cent of the year's production, while the consumption in June, July, August and September only averages 6.4 per cent per month, so that the sewage gas would be produced in the largest quantities when it would be least needed for distribution purposes.

We may summarize our discussion of this phase of the subject by pointing out that although we may assume that sewage gas would afford a reasonably dependable source of supply, yet the maximum production we might expect could rarely exceed 1 per cent of that required for city gas and this would be produced in greatest quantities in the summer when it was least required.

Costs.—It is difficult to secure definite figures on the cost of recovering sewage gas, as the investment and operating costs will depend upon the design of the particular plant involved. A study of the literature appears to indicate that the cost of installing gas collection apparatus would amount to from 2 to 3 per cent of the total plant costs.

In Birmingham, it is estimated that the capital charges and maintenance of the gas collection apparatus amount to approximately 30 cents per 1000 cubic feet (M. C. F.) of gas collected. Here the gas is used in gas engines.

At Halle, Germany, the cost of the gas collection installation amounted to approximately $41,000 and the piping to the central gas plant $22,500 or a total cost of $63,000. Assuming 12 per cent per year for interest, depreciation and operation, we have a yearly cost of $7570 or, on a production of 20,180 M. C. F. per year, a cost per thousand cubic feet of 37.5 cents.

In a plant near Philadelphia where the gas was to be used for heating and to drive an emergency gas engine, the estimated cost of the gas collection apparatus was $2750, with a total plant cost of $146,000, or a little less than 2 per cent. Assuming a yearly production of 900 M. C. F. and 12 per cent on the cost, 1000 cu. ft. would cost 36.7 cents.

At the Charlotte, N. C., plant we have estimated that the gas collection apparatus including the metering, piping and gas holder cost $10,340 in a plant whose total cost was $331,000. This is a little less than 3.5 per cent. If we should include the gas engines the cost would be $16,540 or approximately 5 per cent of the plant cost. Assuming 12 per cent on

the cost of the gas collection with a yearly production of 3261 M. C. F., 1000 cu. ft. would cost 38.1 cents.

Apparently the capital cost of gas collection systems proper will vary from 2.0 to 3.0 per cent of the plant cost. The cost of the apparatus for utilizing the gas will cost from 1 to 2 per cent additional, depending upon whether the gas is to be burned for heating or used in gas engines.

If the figures quoted are representative, we would have the following costs per M. C. F. as shown in Table VI, in which table, in order to more readily compare gases of different heating values, we have also shown the cost per therm of 100,000 B. t. u. as this term is used in the gas industry.

TABLE VI

COST OF COLLECTING SEWAGE GAS

City	Costs per Thousand Cubic Feet	B. T. U. per Cu. Ft.	Cents per Therm. of 100,000 B. T. U.
Birmingham, Eng.	30.0	625	4.8
Conshohocken, Pa.	36.7	700	5.2
Halle, Germany	37.5	675	5.5
Charlotte, N. C.	38.1	700	5.5

The figure of 12 per cent assumed for interest, depreciation and operation would be too low if the gas contained any quantity of hydrogen sulphide and it was necessary to purify it, and this figure, except for Halle, does not include the cost of pipe lines or compression costs to deliver the gas to a central plant for distribution. The cost of pumping gas to a central point including the interest on the pipe line might increase these costs by say 5 cents a thousand or another 0.7 cents per therm.

We do not know of any American plant that has attempted to sell sewage gas for use as city gas. Several German plants have been doing this for a number of years and Table VII summarizes the gas production in five German towns showing the amount of sewage gas produced and the amount received per thousand feet and per therm.

TABLE VII

STATISTICS OF PLANTS SELLING SEWAGE GAS FOR CITY PURPOSES

Place	Population	Sewer Gas per Year	Amount Rec'd per M. C. F.	B. T. U.	Cents per Therm
Essen Rellinghausen	45,000	4,200,000	$0.245	630	3.90
Halle	180,000	20,180,000	0.280	729	3.85
Zurich	200,000	21,200,000	0.350	750	4.66
Stuttgart	350,000	35,000,000	0.560	770	7.27
Münich	500,000	53,000,000	0.700	800	8.76

In considering these figures, however, we must remember that in all the cities mentioned both the sewage disposal and gas plants are owned by the municipality so that the question of the amount paid for the gas

is entirely a question of bookkeeping and does not necessarily represent the true value of the gas as a source of city gas. Furthermore, the amount produced is such a small proportion of the total amount of gas made that the cities mentioned could credit the disposal plant with ten times these prices without appreciably affecting the operating costs of the city gas plant.

It would appear that the only proper way of estimating the value of sewage gas to a plant, for example, in our state is to assume that since the supply is so small there will be no saving to the gas plant in either investment or operating costs and that the sewage gas would merely serve as an enriching agent to increase the heating value of a certain amount of lower heating value gas.

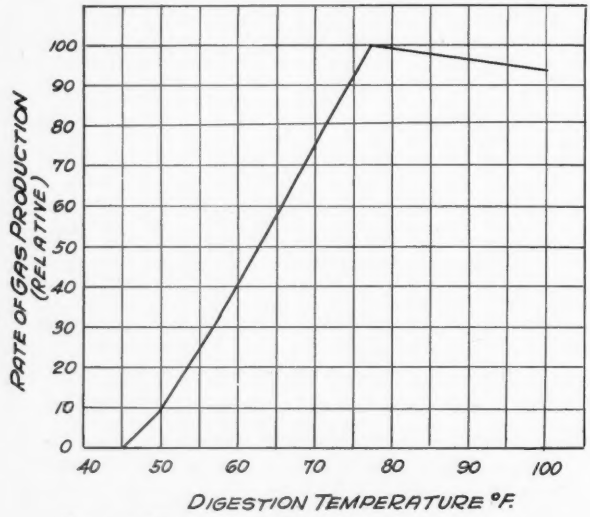


FIG. 1.—Effect of Temperature on Gas Production.

At the present time under these conditions this gas would have to compete with bunker oil which can be purchased for less than, say, 3 cents per gallon, and such oil in passing through the water gas sets would yield approximately 90,000 B. t. u. per gallon and would produce a residual tar credit of about 1 cent per gallon. Thus we can produce an enriching value equal to 0.9 therm for 2 cents or a cost of 2.22 cents per therm.

It is evident that the enriching value of sewage gas is considerably less than the cost of collection, even assuming that no purification, pipe line investment or compression was required.

We may summarize this feature of the problem by pointing out that the value of the sewage gas to a gas company is equal to the enriching

value that could be obtained in some other fashion, and that today enrichment can be obtained for approximately 2.22 cents per therm from bunker fuel oil and that this is a considerably lower figure than the investment and operating costs of collecting the gas.

Justification for Gas Collection.—While we believe we have pointed out in the above discussion that sewage gas is not an economical form of enrichment for city gas, yet we are not opposing the installation of gas collection systems in sewage plants. On the contrary, we believe that wherever the character of the sewage is such as will permit its treatment by digestion tanks, gas collection is not only desirable, but will well repay the investment.

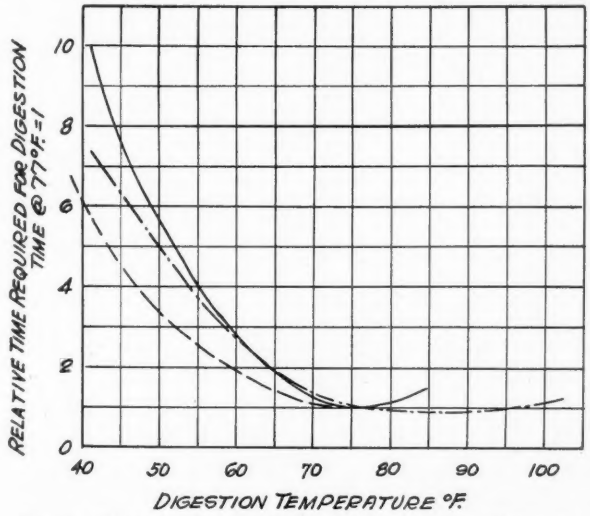


FIG 2.—Effect of Temperature on Rate of Sludge Digestion.

There are two factors to be considered in this connection: (1) the elimination of nuisance; and (2) the decrease in investment cost of the plant due to the increase in digestion capacity that would be secured by maintaining the temperature of the sludge at approximately the optimum point.

Effect of Temperature.—Since digestion is a biochemical reaction, temperature is an important factor. Experience has indicated that there is a minimum temperature below which the reaction proceeds very slowly if at all. There is a critical temperature above which the reaction increases with great rapidity and there is a maximum temperature beyond which the rate of reaction apparently decreases.

Experiments appear to indicate that the minimum temperature is between 40° and 45° F. Below this temperature practically no digestion can be observed. The critical temperature is in the neighborhood of 60° F. Above this temperature the reaction increases quite rapidly and the maximum temperature is between 77° and 80° F., above which temperature there seems to be a decrease in the rate of digestion.

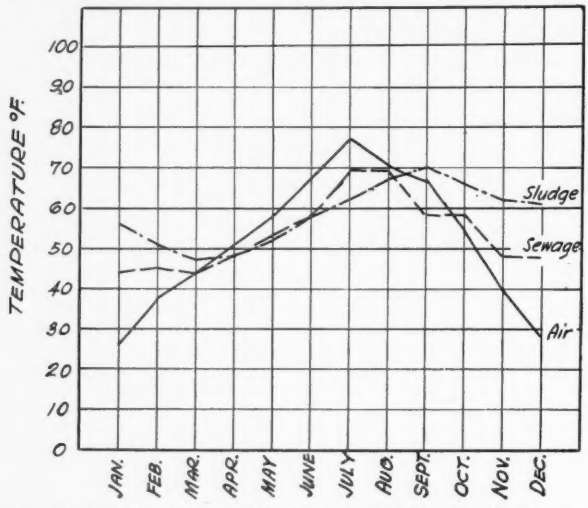


FIG. 3.—Relation between Air, Sewage and Sludge Temperature, Calumet Plant, Chicago, Ill.

The effect of the velocity of the reaction can be shown in a number of ways, as for instance, in the rate at which gas is produced and in the rate at which the digestion proceeds. Figure 1 shows the result of some experimental work of Imhoff which indicates the relative rate of gas production at different temperatures. Another method of expressing these results is given in Figure 2, which shows the time required for digestion as a function of temperature. This data is from results obtained by Imhoff and at Birmingham and Lawrence. It would appear that if the temperature in the digestion tank could be maintained at the optimum, *i. e.*, in the vicinity of 77° F., the capacity of the tank would be increased six times over that obtained if the temperature averaged 50° F. or three times over that if the temperature averaged 60° F.

In connection with the production of gas during digestion, it has been found that, in general, if the temperature is above the minimum, approximately the same quantity of gas will be produced at the different digestion temperatures, but the time required is very greatly increased at the lower temperatures.

The temperature of the sludge in an unheated tank is a function of the air temperatures and Figure 3 shows the relation in the Calumet plant in Chicago between the air temperature, the sewage temperature and the sludge temperature throughout the year. Here it is evident that for about five months of the year the temperature in the sludge was in the neighborhood of 60° F. while for three months it was 50° F. or below, thus indicating the great decrease in the digestive capacity of unheated tanks during the colder months of the year. Of course, this discussion applies only to those latitudes where the air temperature drops below, say, 50° but this condition applies to a very large portion of the United States.

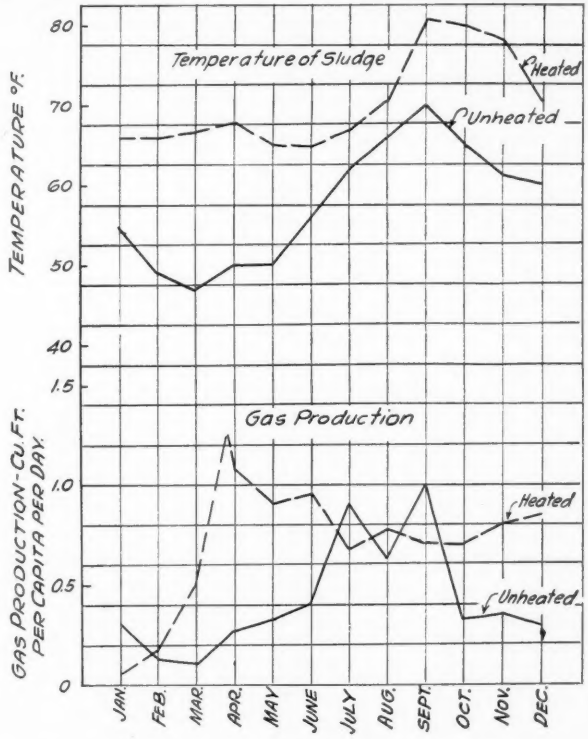


FIG. 4.—Gas Production in Heated and Unheated Tank.

In Figure 4 is shown the gas production from two tanks, Antigo, Wisconsin, was heated, and Calumet, Chicago, was unheated. The very considerable increase in the rate of gas production is quite evident; moreover, the rate of gas production is much more uniform in the case of heated tanks.

The object of this discussion is to indicate the great saving in capacity that accrues from maintaining the temperature of digestion tanks close to the optimum temperature for digestion.

Use of Gas for Tank Heating.—We have previously shown that the temperature of the sludge in the digestion tank determines the time required for digestion and, therefore, the capacity of the tank. We have also shown that the normal temperature of the sludge is some function of the air temperature as is shown in Figure 3. From these data it is evident that in latitudes as far south as North Carolina for a large portion of the year the temperature of sewage is considerably below 77° F. if it ever reaches this temperature, so that digestion never takes place under the most efficient conditions.

It has been found that if the gas is collected and burned so that the heat is applied to increase the temperature in the digestion tanks, the temperature may be maintained above 70° throughout the year and the rapidity of digestion may be very greatly increased. Under these conditions, the capacity of the digestion tanks will be increased, thus increasing the capacity of the whole plant and reducing the investment costs.

We find that the cost of gas collection for this purpose together with the apparatus necessary for utilization would probably not amount to more than 2.5 per cent of the cost of the plant and if this was applied to the plant at Charlotte, N. C., for example, it would mean an installation cost of about $7500.

We estimate that if the tanks were heated to approximately 77° F., sufficient gas would be continuously produced to maintain this temperature and the capacity of the tanks would be increased approximately three times over their present capacity with their present average temperature of 61° F.

We estimate that the digestion tanks at Charlotte cost $20,000 so that if we can increase their capacity three times by an investment of $7500 this would seem to be the most efficient method of utilizing sewage gases.

In addition to increasing the capacity of the digestion tanks, the drying quality of the sludge will be improved and this would probably effect a saving in the area of sludge drying beds required and since the better digested sludge will dry more rapidly and will handle more readily, an additional saving would be made in the handling and disposal of the sludge.

In general, all of our investigation leads us to believe that the collection of the gas can be justified if it is burned to prevent nuisance or if it is used for heating the contents of the digestion tanks, thus increasing their capacity, but that it is not justified in the United States as a substitute for city gas.

Industrial Wastes and Stream Pollution

Packing-Plant Waste Treatment

By M. Starr Nichols* and John Christopher Mackin**

Part I

The centralization of the packing industry and the favorable location of many of the units have made extensive study of the disposal of the wastes a problem of no immediate concern except in a few instances. There is little doubt but that in the future many of the plants now disposing of their wastes untreated will find themselves confronted with the problem of lowering the pollution index of their wastes.

From data obtained from those wastes which have been studied it appears that packing-plant waste has from five to ten times as high an index of pollution as has average domestic sewage. The following tabulation from the results of the Chicago packingtown studies (1921) shows the relative strength of these two wastes.

Determinations	Parts per Million: Domestic Sewage Raw	Parts per Million: Packing-Plant Waste Raw
Organic nitrogen	7.8	79.0
Ammonia nitrogen	9.1	22.0
Nitrite nitrogen	0.1	0.5
Nitrate nitrogen	0.3	3.0
Oxygen consumed	43	269
Biochemical oxygen demand	121	990
Chlorides	40	1000
Suspended solids	144	605

The Sanitary District of Chicago (1914)[1] (1921)[2] has made the most extensive study of the disposal of these wastes. Their studies included screening, settling, chemical precipitation, sprinkling-filter treatment and activated-sludge treatment. Their average results, using the combined treatment of screening, Imhoff settling and sprinkling filters, show a reduction of B. O. D. from 990 p. p. m. to 128, or an 87 per cent reduction. The 1914 report recommended this method of treatment. Further experimental work, using the activated sludge process of treatment (1921), showed a more complete reduction of B. O. D., amounting to about 96

* *Chemist, State Laboratory of Hygiene, and Assistant Professor of Sanitary Chemistry, University of Wisconsin, Madison.*

** *Formerly Assistant Biochemist, City of Madison, Wis. Now Superintendent of Aurora Sanitary District, Aurora, Illinois.*

per cent. It seems that the selection of the activated sludge process in preference to Imhoff tanks and sprinkling-filters was actuated by the smaller amount of space required by the former. Mohlman[3] (1926) summarizes these studies and gives interesting calculations to show the strength of this waste in terms of domestic sewage. Bartow[4] (1926) gives operating results of the treatment of packing-house waste at Mason City, Iowa. Apparently the disposal of the excess sludge has been the greatest problem. Moor and Wayne[5] (1926) reported the results of treatment of packing-plant waste at Fort Worth, Texas. The treatment consisted essentially of eight-mesh screening followed by Dorr clarification. The following summation, compiled from their results, gives a general idea of their work:

AVERAGE RESULTS

	Parts per Million			
	Raw Waste	Screened	Clarified	Per cent Reduction
Total solids	8645	7695	6533	24.5
Suspended solids	2459	1840	670	73.0

From the reported loss on ignition it appears that of the 5863 p. p. m. of soluble solids in the effluent from the clarifier more than 2300 p. p. m. is volatile matter, which probably accounts for the high final 5-day B. O. D. of 1400 parts per million.

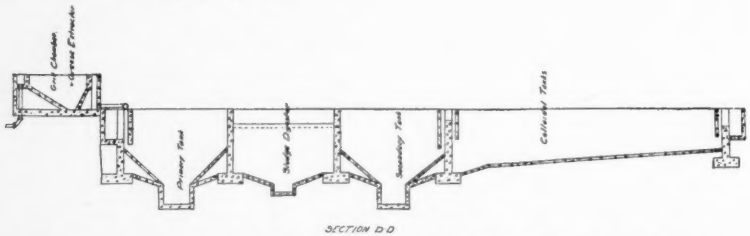


FIG. 1.—Showing General Layout of the Units Used in Treating the Waste by Settling.

The work here reported was done on the waste from the Oscar Mayer Packing Company at Madison, Wisconsin. Their waste previous to 1924 was sent to the city sewer in practically an untreated condition. A separate conduit was then installed and the screened waste was pumped to the city sewage treatment plant separate from domestic sewage. The total volume of packing-plant waste treated at the city plant averaged about 650,000 gallons daily, measured continuously by a recording Venturi meter.

A section of the hopper-bottomed sedimentation tanks and separate sludge-digestion units was used for the sole treatment of the entire volume of packing-plant waste. A grease extractor and grit chamber was con-

FIG. 2.—Showing Slat Aerator in Operation.

structed for preliminary treatment. A longitudinal cross section is shown in Figure 1 of the units used in the treatment of the waste.

The waste from the packing plant, enters the grit and grease chamber from which it flows into the primary settling tank, thence under baffles through a channel across the top of the sludge digestion chamber to the secondary tank. The combined period of detention in these two settling

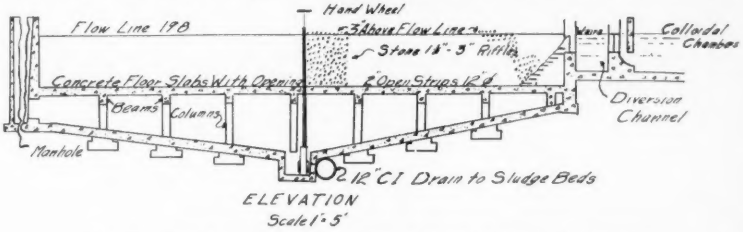


FIG. 3.—Showing General Structure of Contact Dosing Chamber.

tanks averages approximately two hours. The sludge-digestion chamber receives the settled sludge from these two settling tanks. This chamber is provided with suction and discharge pipes so that the bottom sludge can be pumped to the top, fresh sludge added from the bottom of either tank, or digested sludge pumped to the sludge-drying beds.

As the settled packing-plant waste leaves the secondary settling tank it is mixed with an equal volume of domestic sewage and the mixture allowed to flow through the "colloidal" chamber which had been converted to a tertiary settling tank. This tank provides an additional hour for settling the half-and-half mixture of settled wastes. The completely-settled mixture is then allowed to flow over a slat aerator (Figure 2), which was constructed to form a cascade. This cascade aerator was built on top of the rocks in the contact dosing chamber so that when the dosing

chamber is nearly full the lower portion of the aerator is submerged. The mixed waste and sewage, therefore, collects in the contact dosing chamber (Figure 3), just prior to sprinkling-filter treatment. This contact dosing chamber was originally designed to furnish preliminary aerobic treatment but from any chemical tests which have been made,

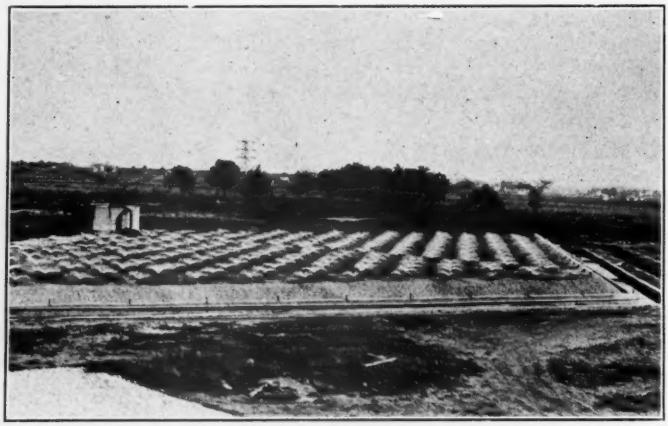


FIG. 4.—Showing Sprinkling Filter, One-third of Which Is in Operation Sprinkling Mixed Effluents. Central Structure Is Siphon Chamber. The Quiescent Part of the Filter Receives Only Settled Domestic Sewage.

there is no proof that such is the case. However, it may provide a transition stage for aerobic action and it does provide capacity and head for the operation of the sprinkling filters.

The effluent from the contact dosing chamber is conducted to the north

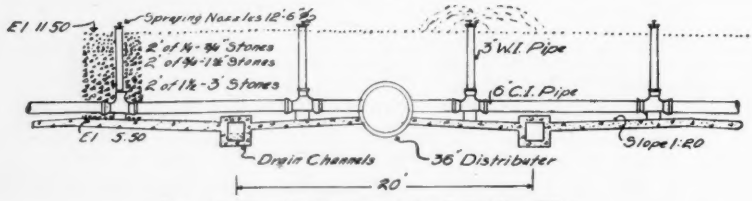


FIG. 5.—Showing Section of the Sprinkling Filter.

sector of the sprinkling filter bed (Figures 4 and 5), on which it is sprayed intermittently. An air-operated siphon chamber controls the application of this effluent.

The final effluent from the treatment process is conducted through the outfall sewer to the point of final disposal.

Sampling.—The sampling points for control analyses were as follows:

raw waste as it enters grit and grease chamber; effluent from primary settling tank; effluent from secondary settling tank and effluent from sprinkling filters. All samples were hourly composites collected over the entire day or during the time the packing plant was in operation.

Methods of Analysis.—The methods of analysis used were those given in *Standard Methods of Water Analysis*, American Public Health Association (1925). The permanganate and oxalate solutions were made so that each cubic centimeter was equivalent to one milligram of oxygen instead of 0.1 milligram. Fats were determined on residues from a 200- to 500-cc. volume of sample by Soxhlet extraction over a 72-hour period, using ethyl ether.

Analytical results were obtained at various intervals over a three-month period in 1927. The arithmetical averages of these results appear in Table I. There were variations in the results obtained from different composite samples but these differences were not so great as to vitiate an average table.

TABLE I

RESULTS IN PARTS PER MILLION

Determination	Raw Waste	Effluent Grit and Grease Chamber	Removal, %	Effluent 1st Primary Tank	Removal, %	Effluent 2d Primary Tank	Removal, %	Effluent Sprinkling Filter	Removal, %	Over-all Removal, %
Total solids	3545	3359	5.2	2625	20.7	2268	10.1	747	42.9	78.9
Suspended solids	846	695	17.8	316	44.8	176	16.5	40	16.1	95.3
Volatile suspended solids	719	594	17.3	266	45.6	152	15.9	33	16.5	95.4
Oxygen consumed	700	722	..	461	34.1	372	12.7	52	45.7	92.6
Biochemical oxygen demand	1266	1190	6.0	888	23.8	672	17.1	108	44.6	91.5
Nitrogen as free ammonia	22.8	22.8	0	25	10.0*	2[illegible]	10.0*	10.6	63.1	3.5
Nitrogen as total organic	145.3	132.6	8.7	100	22.4	74	17.9	8.0	45.4	94.5
Chlorine as chlorides	860	653	..	824	...	696	..	...	..	..
Fats (ether soluble matter)	500	345	31.0	171	34.8	107	12.8	23	16.8	95.4

* Denotes % increase.

Discussion of Results.—From Table I we find that the over-all efficiency of the treatment process ranged above 90 per cent as determined by various factors. It is to be pointed out that the over-all efficiency results as indicated by biochemical oxygen demand and oxygen consumed are well correlated; also that efficiency results as gauged by suspended solids and volatile matter of suspended solids are nearly identical. The efficiency results as shown by total solids would more nearly correspond with the other results if the soluble solids normally present in the carrying water were deducted from both the raw waste and the effluent. This carrying water contained about 450 p. p. m. of soluble solids. Note should be taken of the large reduction of total solids, amounting to 42.9 per cent, as the settled waste passes through the "colloidal" tank contact bed and sprinkling filters, with a corresponding reduction in oxygen consumed, biochemical oxygen demand and total organic nitrogen. There is little doubt but that much settling takes place in the "colloidal" tank and that

much of the 16 per cent of remaining suspended solids from primary and secondary settling are caught in this tank. The free-ammonia nitrogen rises slightly during settling but not enough to indicate septic action to any great extent. This free-ammonia nitrogen is rapidly removed, as shown by the efficiency removal during the sprinkling-filter treatment.

Part II

In the spring of 1928 further studies were made on the treatment of the packing-plant waste. The general scheme of treatment that prevailed during 1927 was followed. In addition to the determinations made during the previous year, phosphorus, total and soluble; potassium; pH; and dissolved oxygen were added as desirable tests on the effluent from certain units.

TABLE II

TOTAL SOLIDS, PARTS PER MILLION

Date Composite Taken	Packing Plant Raw Waste	Effluent Secondary Settling Tank	Effluent Sprinkling Filter
2-1-28	5840	3260	822
2-10-28	4923	3598	883
2-16-28	4862	3317	1037
2-25-28	4325	2798	745
3-1-28	7178	4046	729
3-8-28	5960	3018	877
3-13-28	5015	3288	750
3-21-28	3296	2193	735
3-29-28	5438	3358	846
4-4-28	5937	3043	867
4-11-28	3788	2307	786
4-18-28	3520	2246	825
4-23-28	5395	2942	875
5-3-28	3715	2568	685
5-16-28	4145	2600	710

From a study of Table II, showing results of solids determinations, an idea can be obtained of the variation in composition of the raw waste and effluents. It will be seen that there is some variation in composition of the waste, but the variation from the average is not great.

In Table III we have the summation of the work done during the three-month period, approximately one year after treatment of the packing-house waste was started.

Discussion

From the standpoint of removal of suspended solids, oxidation of organic nitrogen and removal of fats, the plant is operating as efficiently at the end of the year as it was when this control work was begun. The biochemical oxygen demand shows a slightly lowered efficiency. In the next to the last column of Table III is included an average analysis of the settled

domestic sewage with which the settled packing-plant waste is mixed. In the last column is the final effluent from oxidized domestic sewage. These were included to show that while the settled domestic sewage is weaker than the settled packing-house waste the decrease in the pollution index of the mixture can only in part be ascribed to this dilution factor. The decrease in phosphorus and potassium deserve attention. These factors may increase the limits of biological oxidation so that the filters are able to handle the increase in organic matter as furnished by the settled waste. The high B. O. D. of the oxidized domestic sewage (121 p. p. m.) was no doubt due to the fact that the sector of the filter receiving the settled sewage was operating under a load of from 2 to 3 million gallons per acre per day. This was before the Nine Springs Plant was put in operation.

TABLE III

RESULTS IN PARTS PER MILLION

Determination	Raw Packing Waste	Settled Packing Waste	Removal, %	Oxidized Packing Waste	Removal, %	Over-all Efficiency, %	Settled Domestic Sewage	Oxidized Domestic Sewage
Total solids	4888	2973	39.2	811	44.2	83.4	724	656
Suspended solids	1436	279	80.6	88	13.3	93.9	79	72
Volatile suspended solids	1192	230	80.7	70	13.4	94.1	53	54
Nitrogen as free ammonia	47	51	6.4*	21	63.9	57.5	16.3	13
Nitrogen as total organic	254	135	46.8	16	46.9	93.7	12.9	8.5
Oxygen consumed	1213	537	55.7	74	38.2	93.9	70	46
Biochemical oxygen demand	846	581	31.3	167	48.9	80.2	143	121
Dissolved oxygen	....	....	..	2.3	..	..	...	3.3
Soluble phosphorus (as P)	11.2	7.7	40.1	3.1	41.1	81.2	...	2.4
Total phosphorus (as P)	45	17.5	61.1	6.3	24.8	85.9	...	4.8
pH	7.6	7.7	..	8.0	..	..	...	8.0
Potassium (as K)	45.6	42	7.9	10.6	69.8	77.7	...	8.4
Fats (ether soluble matter)	336	94.6	71.9	15.0	23.7	95.6	...	13.0

* Denotes % increase.

Summary

Experimental results are presented to show the effect of plain sedimentation and sprinkling-filter treatment of packing-plant waste. Over-all efficiencies during a period of somewhat more than one year show that this method of treatment as applied at Madison, Wisconsin, can reduce the pollution strength of this waste to less than 10 per cent of its original content. The results obtained from analyses of the raw waste and final effluent after the plant had been in operation one year show that while the

biochemical oxygen demand of the final effluent was slightly higher, the efficiency as determined by all other tests remained practically the same as it was when the plant was put in operation.

The authors wish to acknowledge the helpful consideration accorded them by Mr. James H. Mackin, Superintendent of Sewage Disposal, Madison, Wis., and Mr. E. E. Parker, City Engineer, as well as the valuable suggestions of Dr. B. P. Domogalla, City Biochemist, Madison, Wis.

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[2] *Ibid.* Volume II. 1921. Langdon Pearse.

[3] Mohlman, F. W., "Treatment of Packing-House, Tannery, and Corn Products Wastes," *Ind. Eng. Chem.*, **18,** p. 1076, 1926.

[4] Bartow, Edward, "Disposal of Some Organic Trade Wastes," *Ind. Eng. Chem.*, **18,** p. 1085, 1926.

[5] Moor, W. C., and Wayne, W. P., "The Treatment of Packing-House Sewage," *Ind. Eng. Chem.*, **18,** p. 239, 1926.

Admission of Trade Effluents into Sewers. *The Surveyor*, **78,** 11, July 4, 1930. The British Joint Advisory Committee on River Pollution has issued a report recommending repeal of the general law and Section 7 of the River Pollution Prevention Act of 1876. Present legal authority, resting on the Act of 1876, is declared to be inadequate. A new code is needed which will clearly define the rights and obligations of trader and local authority, will be uniform in its application, but will admit of variation in detail to suit local conditions.

The committee recommended the following amendments to the general law regarding stream pollution: *a.* The local authorities should receive trade wastes if possible. *b.* Agreements should be reached between trader and sanitary authority, subject to final decision by the Minister of Health. *c.* The sanitary authority may call for necessary preliminary treatment and removal of specified substances, where practicable, and may regulate the rate and volume of discharge, impose reasonable charges for the facilities afforded, and provide for measurement of quantities, inspection of effluents and collection of samples. *d.* Separate sewers may be provided for treatment of the wastes alone, if necessary, at the manufacturer's expense. *e.* Sludge may be removed from the trader's premises at his expense. *f.* The sanitary authority may have the right of entry into the factory. *g.* The sanitary authority may expressly be authorized to enter into agreements as to terms on which trade wastes should be accepted. *h.* Certain substances should be definitely excluded from the sewers. *i.* Existing riparian rights are to be maintained. *j.* The Minister of Health may have power to extend or suspend the regulations as deemed necessary. The committee recommends early legislation on these recommendations.

Editorial

Chlorine for Pooled Trickling Filters

A Testimonial

One of the favorite advertising devices for remedies of a bygone day was the signed testimonial accompanying "before" and "after" photographs. Modern science scorns this type of publicity, but it still has its uses.

Chlorine has been used frequently for relief of ponded trickling filters and numerous articles have been written to report the effect of such treatment. Most of these articles have described the method of application and the amounts applied, with a statement that the films or growths on the filter stone sloughed off as a result of the chlorination, leaving the stone clean and bare. These articles have never been particularly impressive since the casual reader could not visualize the actual physical consequence of such a cleaning action. Now, however, we have an article which is so impressive by its pictorial history alone that there can be no doubt as to the efficacy of chlorine for relief of ponded filters. The experiments made by Mr. E. E. Smith at Elgin, Illinois, described on page 387 of this issue, are of great interest and fortunately he has preserved the history of the tests by excellent "before" and "after" photographs. Conditions were unusually satisfactory for a convincing demonstration of the effect of chlorine, since each half of the filter was dosed by a separate dosing-chamber, whereby one-half of the plant could be held as a control while the other half was treated with chlorine. The photograph taken after the east bed was treated, but before the west bed was treated (Fig. 4, p. 389) proves that the unloading was not a normal seasonal affair, which might have occurred even though no chlorine had been applied, but that the chlorine was responsible for the loosening and discharge of the thick film which was clogging the surface of the filter. The results seem almost miraculous. When one contemplates the immense amount of hard work that would have been required to loosen and discharge the clogging films by plowing, harrowing, picking or flushing, and then considers the ease with which the job was done, it seems as though the chlorine were some magic product of the alchemist's art. It would be difficult to imagine worse pooling than is shown by the "before" photograph, or cleaner stone than that shown "after" application of chlorine.

Although the Elgin experience is not proof that the same results may

be obtained elsewhere, the striking success, considered in addition to previous tests, demonstrates that chlorination should receive primary consideration for relief of ponded filters.

Pioneers of Public Health

Public-health activities of the present day are so varied that the treatment and disposal of sewage is usually only one of many other municipal or state functions established for the preservation of public health. Shortly before the turn of the century, however, investigations of sewage treatment and stream pollution occupied a larger share of the state health activities, particularly in Massachusetts. Mr. Eddy writes reminiscently of this period, although he neglects to mention the large share he has had in the development and progress of sewage treatment in Massachusetts and throughout the United States.

Those pioneers of the eighties and nineties who established the Lawrence Experiment Station were followed by a later, although overlapping generation, which extended their work at the Technology Experiment Station, under the direction of Profs. Winslow and Phelps. This continuity of active investigation, extending over twenty-five years, is still unbroken after forty years. Mr. Harry W. Clark, who started his professional career at the Lawrence Experiment Station in 1888, is still in charge of that work. The development of scientific sewage treatment has been so rapid that in one man's professional lifetime we have progressed from pioneering investigations of the biological nature of sewage purification to the enormous and complex activated-sludge plants of the present day.

The charge that was given to the Massachusetts State Board of Health in 1886 by the Drainage Commission may still serve as a model for those responsible for the treatment of sewage and the purification of polluted streams:

"Let those guardians of inland waters be charged to acquaint themselves with the actual condition of all waters within the state as respects their pollution or purity, and to inform themselves particularly as to the relation which that condition bears to the health and well-being of any part of the people of the commonwealth. Let them do away, as far as possible, with all remedial pollution, and use every means in their power to prevent further vitiation. Let them make it their business to advise and assist cities or towns desiring a supply of water or a system of sewerage. They shall put themselves at the disposal of manufacturers and others using rivers, streams or ponds, or in any way mis-using them, to suggest the best means of minimizing the amount of dirt in their effluent, and to experiment upon methods of reducing or avoiding pollution. They shall

warn the persistent violator of all reasonable regulation in the management of water, of the consequences of his acts. In a word, it shall be their special function to guard the public interest and the public health in its relation with water, whether pure or defiled, with the ultimate hope, which must never be abandoned, that sooner or later ways may be found to redeem and preserve all the waters of the state."

Although this ultimate hope has not been fully attained, we still have faith in the methods by which it was proposed to accomplish the redemption of polluted waterways.

Mr. Eddy has contributed notably toward the attainment of the objectives of his predecessors. His loyalty to Massachusetts may be expressed in the words of former President Coolidge, when referring in 1919 to Col. Ephraim Williams, founder of Williams College: "There speaks with the voice of immortality one who loved Massachusetts."

Proceedings of Local Associations

Federal Sewage Research Association

The United States Public Health Service group has organized the Federal Sewage Research Association. This group has become affiliated with the Federation. At present the Association has twenty members. The officers are: *President*, H. W. Streeter, Cincinnati, Ohio; *Vice-President*, L. M. Fisher, New York City; *Secretary-Treasurer*, A. P. Miller, Washington, D. C.; *Members of Executive Committee:* L. C. Frank, Chevy Chase, Md., and J. K. Hoskins, Cincinnati, Ohio.

Michigan Conference of Sewage Works Operators Sixth Annual Meeting

East Lansing, Michigan

April 17–18, 1930

Through the courtesy of Michigan State College the Sixth Annual Meeting of the Michigan Sewage Works Conference was held at Olds Hall, Michigan State College, East Lansing, April 17 and 18, 1930.

Professor F. R. Theroux welcomed the members of the Conference in behalf of Michigan State College and extended to the members the hospitality of the College.

Mr. Walter A. Sperry, Executive Secretary and Chief Engineer of the Michigan Stream Control Commission, presented a very interesting talk on the problems which come before the Commission. Following Mr. Sperry, Mr. John Jellema, Chief Chemist, Holland Sewage Treatment Works, gave a brief and instructive talk on the experiences at the Holland plant, bringing particular attention to the attempted control of pH of sludge by the use of lime.

The afternoon session was opened by a paper by Mr. C. P. MacGrath, whose subject was "Stream Pollution from the Viewpoints of Epidemics and the Law." Mr. MacGrath talked very instructively and entertainingly upon his subject, quoting freely from various cases where epidemics of disease had been traced to stream pollution and also of instances where individuals had been awarded damages because of injury to property or health.

The Conference was also very fortunate in having present Mr. C. C.

Hommon of Canton, Ohio, who gave an excellent talk on the practical side of the operation of sewage treatment plants. Of particular interest were Mr. Hommon's experiences with sprinkling filters.

Mr. Harry Johnson, President of the Conference and Superintendent of the Flint Sewage Treatment Works, gave an interesting talk on the experiences encountered in the second year of operation at the Flint plant. Studies of conditions in the Flint River, odor control and sludge circulation and pre-aeration experiments were the high lights of the year.

Mr. H. A. Olsen, special sanitary engineer at Pontiac, gave a talk on the experiences at the Pontiac plant. Mr. Olsen outlined the program of sewer construction being carried on by the city together with the extension of the present plant.

F. W. Jones of Cleveland, Ohio, presented a very instructive talk to the members on the design and operation of sewage treatment plants.

At a business meeting the following officers were elected: *President*, H. A. Olsen, Pontiac; *Vice-President*, C. P. MacGrath, St. Clair Shores; *Secretary-Treasurer*, W. F. Shephard, Michigan State Dept. of Health; *Directors*, Fred Dorr, Royal Oak and R. Anderson. By unanimous vote the Conference voted to affiliate with the Federation of Sewage Works Associations and an assessment of $1.50 each was made. It was also voted to hold the next meeting not later than November 15, 1930.

Pennsylvania Sewage Works Association Fourth Annual Conference

State College, Pennsylvania

June 26-27, 1930

The Fourth Annual Meeting of the Pennsylvania Sewage Works Association was held at the Pennsylvania State College, June 26 and 27, 1930. This followed the Third Annual Meeting of the Pennsylvania Water Works Operators' Association, which was held June 24 and 25. There were ninety-seven registered at the sewage works meeting.

The conference was welcomed by A. O. Morse, Executive Secretary to the President of State College and by R. O'Donnell, Professor of Hydraulic and Sanitary Engineering. The papers presented June 24 were: "Observations upon Operation of European Sewage Works" by George B. Gascoigne, Consulting Engineer of Cleveland, Ohio, and "Westchester County Metropolitan Sewerage Development" by Eugene S. Martin, Secretary, Westchester County Sewer Commission, New York.

The afternoon session was devoted to a symposium on operation by plant operators in Pennsylvania. Those contributing were: Thomas

Nevin of Philadelphia and F. G. Nugent of New Castle, on Imhoff tanks; Edwin B. Wagner, Downington, and G. M. Grace, Polk, on trickling filters; H. N. Blunt, Palmerton, Isaac Slaw, Wayne, and F. E. Daniels, Harrisburg, on intermittent sand filters; S. M. Fisher, Sharon, and Paul Shaftner, Butler, on separate sludge digestion; and Dr. Clarence E. Fox, Lebanon, and R. R. Cleland, State College, on sludge beds.

Mr. George H. Shaw, District Engineer, Eastern Clay Products Association, Philadelphia, gave a talk on "Vitrified Clay—Its Use in Sewers and Sewage Treatment Works" following the symposium.

In the evening a dinner was held at the Center Hills Country Club followed by a round-table discussion.

On Friday morning, June 27, Mr. Herman Kratz, Jr., Junior Chemist at the Back River Sewage Treatment Works, Baltimore, Maryland, gave a paper on "Operation of Trickling Filters at Baltimore."

"Gas Collection at Sewage Treatment Works" was discussed by W. H. Fulweiler, Chemical Engineer of the United Gas Improvement Company, Philadelphia.

Harrison P. Eddy, Jr., of Metcalf and Eddy, Boston, Mass., discussed "Digestion of Sewage Sludge in Separate Tanks."

"Sewage Plant Operation by pH Control" was presented by Dr. Willem Rudolfs, Chief of the Department of Sewage Research at the New Jersey Agricultural Experiment Station, New Brunswick, New Jersey.

The following officers were elected for the ensuing year: *President*, Harry M. Beaumont, Philadelphia; *First Vice-President*, Lowell W. Monroe, Elwood City; *Second Vice-President*, R. O'Donnell, State College; *Secretary-Treasurer*, L. D. Matter, 56 W. Union Street, Wilkes-Barre; *Representatives, Board of Control*, C. A. Emerson, Jr., Philadelphia, and H. E. Moses, Harrisburg.

Central States Sewage Works Association Third Annual Meeting

Springfield, Illinois

June 9–10, 1930

The Third Annual Meeting of the Central States Sewage Works Association was held June 9–10, 1930, at the Abraham Lincoln Hotel, Springfield, Illinois. The total registration was sixty-five, but a number of guests increased the attendance at some of the sessions to approximately eighty-five. A large number of advance notices, with follow-up cards, had been sent out by Secretary Gus H. Radebaugh. An excellent pro-

gram had been prepared, mainly due to the efforts of Mr. Frank R. Theroux, Chairman of the Program Committee.

The meeting was called to order by President Lewis S. Finch at 10 a.m. Monday morning. President Finch outlined the program and the inspection trips through the Springfield plant and later through the Decatur or Bloomington plants. The report of the Secretary, Gus H. Radebaugh, of Urbana, Illinois, indicated that there had been a gain of forty members since the meeting in Indianapolis in June, 1929, making a total of 139 paid-up memberships. During the course of the Springfield meeting approximately twenty-five additional members joined the Association, bringing the total membership up to approximately one hundred and sixty-five.

The Treasurer, Mr. C. K. Calvert, reported that the financial affairs of the Association are in first-class condition. Mr. Calvert has spent a large amount of time in following up delinquent members, in some cases sending out as many as eight letters before receiving the members' dues, but his tenacity has kept the membership list complete, with very few resignations.

The technical sessions of the meeting started at 10:15, Monday morning, with a paper by Dr. M. Starr Nichols, Chemist of the Wisconsin State Laboratory of Hygiene, whose paper on the treatment of packing-house wastes at Madison appears in this issue. Dr. Nichols' paper at Springfield was concerned with the function of laboratory surveys in sewage treatment. The paper outlined very completely the various types of laboratories required for plants of different degrees of complexity and size; small plants and operators' laboratories can carry on only the more simple tests, which were described by Dr. Nichols. For larger plants a control laboratory can handle a more complete series of analytical determinations, which were listed by the speaker. Further standardization of control laboratories may be effected by a central or state-controlled laboratory or by one of a mobile type. It is also desirable to have a central or field research laboratory in order to cope with the variety of problems encountered in any state. Some stimulating suggestions were brought up by Dr. Nichols concerning needed research on methods of sewage analysis. The paper was discussed by Messrs. Mohlman, Hatfield and Mackin.

The second paper, by Mr. O. M. Leonard of Frankfort, Indiana, presented operating results for the first year of operation of the Imhoff tank-trickling filter treatment works at Frankfort. Mr. Leonard has developed rather novel operating ideas. Gas from Imhoff tanks is used for heating the laboratory and administration building, and it is intended to pipe the surplus gas during the summertime to the municipal swimming pool for heating water in the shower baths and likewise a gas line will be run to

the tourists' camp, which is approximately one-half mile from the sewage treatment works. This paper was discussed by Messrs. Nichols, Sperry, Hatfield and Kivell.

A pleasant feature of Monday morning's program was the presence of Mr. Walter A. Sperry, Executive Secretary and Engineer of the Michigan Stream Control Commission, who presented a paper on "Control of Stream Pollution in Michigan." Mr. Sperry outlined the rather determined effort that is being made in Michigan to force the installation of sewage treatment works in order to alleviate pollution of the streams of that state, which is the leading summer playground of the Middle West. The paper was discussed by Messrs. Radebaugh, Nichols and Finch.

The last paper, presented at 11:45, Monday morning, was "Trend of Developments in Separate Sludge Digestion" by Wayne A. Kivell, Sanitary Engineer, The Dorr Company. Mr. Kivell brought information concerning the most modern types of separate digestion tanks throughout the country, with particular reference to mechanical devices that have been used for improvement of digestion, collection of gas, prevention of scum formation and disposal of sludge. The paper was discussed by Mr. Leonard and others.

Luncheon was served in the hotel at 12:30, followed by an address of welcome from a representative of the Mayor, the Honorable Hal M. Smith, with a reply by President Finch. The Trustees of the Springfield Sanitary District, Messrs. Sidney S. Breese, George T. Kresse and Harry F. Ferguson, were presented to the Association and they extended a welcome to visit the Springfield Sewage Treatment Works.

The meeting Monday afternoon opened with a paper by Mr. Edwin C. Hurd of Indianapolis on "Making and Interpreting a Sanitary Survey." Mr. Hurd outlined the basic data required in making a preliminary survey for collection of material for plant design. He discussed particularly the necessity and procedure for proper sampling and the use of the analytical data thus obtained. His paper was discussed by Mr. Mays of Michigan.

At 2:00 p. m. Mr. J. J. Woltmann of Taylor and Woltmann, Engineers, Bloomington, Illinois, described the operation of the Imhoff tank-trickling filter plant of that city. The paper is published in this issue. The Chairman of our Federation, Mr. C. A. Emerson, Jr., had appeared at the meeting by this time and he contributed a discussion of this paper with particular reference to control of sludge digestion and collection of gas.

The next paper was "The Correlation of Suspended Solids and Biochemical Oxygen Demand of Activated Sludge Effluents" by Miss Gladys Swope of the Sanitary District of Chicago. This paper presented a series of results on effluents from the North Side (Chicago) activated sludge plant, which indicated that an increase of suspended solids from 10–15 up to 50 p. p. m. did not result in a correspondingly great increase in 5-day

biochemical oxygen demand but when the B. O. D. incubation was carried out to twenty days a larger percentage increase was found. The paper was discussed by Messrs. Mohlman and Calvert.

One of the most interesting papers of the meeting was presented by Mr. E. E. Smith, Superintendent of the Elgin (Illinois) Sanitary District, on "Control of Filter Growths by Chlorination." The paper is published in this issue. A lively discussion followed, participated in by Messrs. Enslow, Hatfield, Mackin and Brensley.

Mr. B. H. Jeup of Jeup and Moore, Engineers, Indianapolis, read the next paper, "Some of the Factors Determining the Size and Control of Intercepting Chambers in Combined Sewer Design." Interceptor overflows based on studies of the oxygen demand of the stormwater sewage and the oxygen resources of the receiving body of water were recommended by Mr. Jeup. The continuous operating care necessary for efficient operation of storm-water controls was discussed by Mr. R. S. Smith of the Des Plaines Treatment Works of the Sanitary District of Chicago.

The next paper, although not on the program, was presented by Mr. Max Suter of Jacksonville, Illinois, who told about sewage treatment in Europe. He described innovations and modifications of standard types of sewage treatment devices which he had inspected during a recent trip to Europe.

Late in the afternoon committee reports were received and it was decided to combine the offices of secretary and treasurer into one office which was conferred upon Gus H. Radebaugh of the Urbana-Champaign Sanitary District, Urbana, Illinois.

The social feature of the meeting was the dinner and smoker Monday evening. The Association was fortunate in obtaining as principal speaker Colonel Robert Isham Randolph, President of the Chicago Association of Commerce and member of the Randolph-Perkins Company, Engineers, of Chicago. Colonel Randolph has been for many years a consulting engineer of the Chicago Sanitary District and his father was the best known of the Chief Engineers in its early days. Colonel Randolph spoke on the history of the Sanitary District and its future program. His remarks were confined to a concise but comprehensive statement of actual matters of fact with reference to the Sanitary District's sewage treatment program and the history of the Drainage Canal, with all the litigation that has occurred in the past thirty years.

After short addresses by various other speakers motion pictures were shown of the construction work of the intercepting sewers and the Springfield treatment works.

The technical session Tuesday morning opened with a paper on "Industrial Waste Problems in Municipal Sewage Treatment," by L. F.

Warrick, State Sanitary Engineer, and E. J. Beatty, Assistant Engineer, Wisconsin State Department of Health. This paper, read by Mr. Beatty, described the importance of industrial waste problems, particularly in Wisconsin; a general history was given of the special investigations and studies that have been made in Wisconsin concerning cannery wastes and paper mill wastes. The paper was discussed by Dr. Nichols and by Mr. E. F. Eldridge of East Lansing, Michigan, who has been conducting experiments on biological treatment of milk products wastes.

The next paper was a lengthy description of activated sludge experiments at the Calumet Sewage Treatment Works by F. W. Mohlman and C. E. Wheeler, Chicago Sanitary District. This paper reviewed the developments of mechanical processes of activation for reduction of power requirements, also of stage processes of aeration for reduction of period. Detailed data were presented showing results of large-scale experiments at the Calumet Works with a paddle-wheel, diffused-air unit and a two-stage unit of novel design. The paper was discussed by Messrs. Hatfield, Enslow and J. I. Smith.

The next paper, "Sewage Filter Media and Loadings," by William E. Stanley of Pearse, Greeley and Hansen, Engineers, of Chicago, was presented by Mr. Samuel Greeley. This paper was a concise summary of the large amount of work Mr. Stanley has supervised as chairman of the committee of the American Society of Civil Engineers on composition of trickling filter media, with regard to size of material, depth and loading of filters. The paper was discussed by Messrs. Mackin, Buswell and Calvert.

Dr. W. D. Hatfield, Superintendent of the Decatur Sanitary District, next read a paper on "Determination of Biochemical Oxygen Demand." Various dilution waters have been used in Dr. Hatfield's work with quite variable results, particularly very low results when using distilled water. Research indicated that it is inadvisable to have rubber stoppers or seals in contact with the diluted sample, since Dr. Hatfield's results showed a considerable utilization of oxygen by rubber stoppers, the amount of absorption increasing in proportion to the area of rubber exposed. This paper was discussed by Messrs. Mohlman, Barnett, Nichols, Hurd and Radebaugh. Mr. Radebaugh urged that a further study be made through the appointment of a national committee by Chairman Emerson, or by directed individual effort, of Standard Methods of Sewage Analysis, particularly with reference to B. O. D. determination. The symposium appearing in this issue of THIS JOURNAL on Standard Methods of Sewage Analysis was prepared by the Editor sometime previous to this meeting in consideration of the need for such work, as expressed by Mr. Radebaugh.

Dr. A. M. Buswell spoke next with regard to the procedure recommended by him for prevention of scum formation in Imhoff and separate

digestion tanks, comprising mainly circulation of sludge liquor with distribution over the surface of the scum. Dr. Buswell summarized his work at Urbana and mentioned the use of this scheme at Decatur, Illinois, and Blacksburg, Virginia, with successful results. The paper was discussed by Messrs. Enslow and Theroux.

An interesting illustrated description of the Springfield Sewage Treatment Works was next given by Mr. Samuel A. Greeley of Chicago, who supervised the design of the intercepting sewers and treatment works.

The luncheon held at 12:30, Tuesday, was featured by an address by Chairman C. A. Emerson of the Federation of Sewage Works Associations. Mr. Emerson's remarks were concerned mainly with the growth and aims of the Federation, with a history of its formation and the success that had followed the inauguration of local associations. Following this address there was a discussion of the SEWAGE WORKS JOURNAL led by F. W. Mohlman, Editor, who made a plea for the submission of more articles dealing with practical details of plant operation. Various proposals for obtaining these articles were discussed. The luncheon was followed by a trip to the Springfield Treatment Works. Technical details of the plant were described by H. F. Ferguson, Trustee; W. B. Walraven, Engineer; and C. C. Larson, Chemist. This plant is of great interest in that it contains Link-Belt and Dorr preliminary settling tanks, activated sludge treatment for part of the settled effluent, digestion of settled and activated sludge in heated separate digestion tanks with floating covers and collection of gas, which is used in the laboratory and for heating of sludge, open and glass-covered sludge beds and an administration building with a fine chemical and bacteriological laboratory, which has been described in THIS JOURNAL by Mr. Ferguson.

A large party of those present at the Springfield plant drove to the Decatur Treatment Works where an explanation of the plant was made by Dr. W. D. Hatfield.

After a warm welcome from Dr. Nichols it was decided to hold the next meeting at Madison, Wisconsin. The new officers elected for the coming year are as follows: *President:* F. W. Mohlman, Chicago; *First Vice-President:* L. F. Warrick, Madison, Wisconsin; *Second Vice-President:* C. K. Calvert, Indianapolis, Indiana; *Secretary-Treasurer:* Gus H. Radebaugh, Urbana, Illinois.

Maryland-Delaware Water and Sewerage Association Fourth Annual Conference

Hagerstown, Maryland

May 13–14, 1930

This Association, formerly known as the Maryland Water and Sewerage Association, officially became the Maryland–Delaware Association at the Fourth Annual Conference held on May 13 and 14, 1930, at the Hotel Alexander in Hagerstown, Maryland. This was the largest meeting the Association has held, there being 140 persons registered.

The papers read and discussed covered topics on both water and sewage problems, those dealing with sewage being: "Determination of Oxygen Demand by the Direct Oxygen Method," by Edward C. Cromwell; "Sewage Treatment Problems at Hagerstown," by W. C. Slee and L. R Voris; "Regular Supervision of Institutional Water and Sewage Treatment Plants in Maryland," by A. W. Blohm; and "European Methods of Sewage Treatment," by C. E. Keefer.

The Hon. Harry Holzapfel was the speaker at the annual banquet on May 13. A round table discussion was held after the banquet.

Inspection trips were made to the Hagerstown sewage treatment plant, and to Hagerstown's new water works plant on the Potomac River near Williamsport, Maryland.

The officers elected for the ensuing year are: J. G. Patrick, Luke, Md., *President;* Harry R. Hall, Hyattsville, Md., *First Vice-President;* R. C. Beckett, Dover, Del., *Second Vice-President;* F. W. Caspari, Baltimore, Md., *Secretary;* and E. S. Hopkins, Baltimore, Md., *Treasurer.* Wm. Krumbine was elected a member of the executive committee to serve for one year.

New York State Sewage Works Association Second Annual Meeting

Albany, New York

May 10, 1930

The Second Regular Annual Meeting of the New York State Sewage Works Association was held May 10, 1930, in Albany. In the absence of the President, Kenneth Allen, the Vice-President, C. A. Holmquist, presided. Sixty-one members and guests were present.

The morning session was devoted to the regular business of the Association and to the presentation and discussion of two papers, one on "Operating Experience at the Syracuse Treatment Works," by W. P. Gyatt,

chief operating engineer, and the other on "Essentials of Operation and Control of Small Sewage Treatment Plants," by C. C. Agar of the State Department of Health.

Wellington Donaldson (New York City), W. A. Ryan (Rochester) and C. L. Walker (Ithaca) were elected members of the Executive Committee for a term of three years to succeed the retiring members, R. Suter, R. H. Gould and Kenneth Allen. Mr. Allen, however, will continue to serve on the Executive Committee for another year as an advisory member. The officers for the ensuing year are: C. A. Holmquist, *President*, Morris M. Cohn, *Vice-President*, and A. S. Bedell, *Secretary-Treasurer*.

The report of the Committee on the Short School for Sewage Works Operators was received with considerable interest as definite plans are being formulated for holding a one-week school at Schenectady during the coming autumn.

At the luncheon held in the DeWitt Clinton Hotel, Mr. C. A. Holmquist presented the greetings of Dr. Parran, the State Commissioner of Health, indicating his sincere interest in the aims and activities of the Association. Following the luncheon, there was a lively round table discussion on the effect of industrial wastes on the operation of municipal sewage treatment plants, the propriety of allowing cellar drains to be connected to the sewer system and the specifications for house connections, led by R. S. Lanphear, R. C. Wheeler and Fred Fisch.

The meeting closed with an inspection trip to the sewage treatment plant of the City of Albany, and to the treatment works serving the Albany County Buildings where very complete treatment and odor control were well exemplified.

The next meeting of the Association will be held September 13, 1930, in Syracuse, Glenn D. Holmes serving as chairman of the local committee on arrangements.

Notice of Fall Meeting

The Fall Meeting of the New York State Sewage Works Association will be held on September 13, 1930, at Syracuse, New York.

California Sewage Works Association Second Spring Conference

Sacramento, California

April 21–22, 1930

The Second Spring Conference of the California Sewage Works Association assembled April 21, 1930, at the Hotel Oaks, Chico, California. The total registration was 113. An inspection trip was made to the Chico

plant, the University Farm disposal plant at Davis, and to the Lodi and Sacramento disposal works.

The Chico plant is Dorr-equipped and consists of mechanically cleaned bar screens, a clarifier with skimmer and automatic screen, and a separate sludge digestion tank equipped for heating and gas collection. The effluent is ponded and used for irrigation of a sewer farm.

The 33-car caravan then visited the University Farm at Davis where luncheon was served, after which an inspection was made of the treatment plant. This is an Imhoff plant followed by sprinkling filters and secondary settling tanks. A novel feature during this visit occurred when three freshmen high-school students read essays on the operation of the plant. A managers' and operators' school was held, during which the use of tools was demonstrated, simple laboratory tests explained and measuring devices demonstrated for irrigation water, which might be applicable for sewage or effluents.

The caravan reached Sacramento about 7:00 p. m. when dinner was served in the Hotel Sacramento, followed by a round table discussion. Mr. F. A. Batty, President, presided. The topics discussed were: "Tree Roots in Sewers" and "Manhole Spacing." Mr. R. F. Goudey gave his impressions of eastern plants, which he had just visited, and W. L. Jencks described a new sewer joint.

The next morning the party visited the activated-sludge plant at Lodi. The sewage passes from a bar screen through a fine-screening chamber with a Dorr cylindrical screen, to a wet well, from which it is lifted by Byron Jackson pumps to the influent channels, where it is mixed with activated sludge. It then passes to the aeration tanks. The effluent is chlorinated and used for irrigation. Sludge is collected in a Dorr clarifier and forced to a sludge-return channel where it is reaerated. Screenings are buried and sludge is dried on open beds.

A managers' and operators' school was also held at Lodi and simple laboratory tests were demonstrated. The members were guests of the City of Lodi at a luncheon held in the Women's City Club.

The screening and pumping plants at Sacramento were inspected in the afternoon.

Dinner was held at the Hotel Senator at Sacramento. F. A. Batty, President, explained the objects of the Association and introduced John F. Coleman, President of the American Society of Civil Engineers, and four student chapter presidents. A bronze plaque donated by Wallace and Tiernan was presented to the University Farm for having the best designed and operated plant. A cash prize of twenty-five dollars was given to the operator, John Jacobson. The prize was donated by the Dorr Company, Great Western Electro-Chemical Company, Water Works Supply Company and Western Construction News.

John W. Alvord, consulting engineer, Chicago, was the principal speaker of the evening. His subject was "Biological Engineering."

Harrison P. Eddy, consulting engineer, Boston, was the other notable guest and speaker. Mr. Eddy reviewed sewage disposal from its early beginnings in 1880 in England. He discussed the difficulties of the present-day sewage-works operator and concluded that an organization such as the California Sewage Works Association could materially aid in gaining the support of municipalities for plant operators.

After an informal discussion of these papers the meeting adjourned.

New England Sewage Works Association
Second Annual Meeting

Boston, Mass.

April 15–16, 1930

The Second Annual Meeting of the New England Sewage Works Association was held Tuesday and Wednesday, April 15–16, 1930, at the Hotel Statler, Boston.

The meeting was held in connection with that of the New England Health Institute. The program for the morning session, held at the Hotel Statler, was arranged by the Sanitary Engineering Division of the Health Institute.

The first paper, "The Future Task of the Engineer in Public Health," was presented by Mr. Abel Wolman, Chief Engineer of the Maryland State Department of Health, and was discussed by Prof. Gordon M. Fair of Harvard University.

The second paper, "Massachusetts, the Cradle of Public Health Engineering," by Harrison P. Eddy of Boston, was read by Harrison P. Eddy, Jr., and discussed by Prof. Fair of Harvard University.

The last paper of the morning session, "Sewage Disposal," was presented by H. W. Clark, Chief Chemist of the Massachusetts State Department of Health, and was discussed by Robert Spurr Weston, Boston.

After a luncheon recess the afternoon session of the Association resumed at the Hotel Brunswick. Following a brief business meeting, the Committee on Plant Records, Mr. Warren J. Scott, Chairman, presented a progress report.

The first paper of the afternoon session, "Sewer Rentals," was presented by Mr. Harold S. Crocker, City Engineer of Brockton, Mass. This paper provoked considerable interesting discussion.

This was followed by a paper on "Stream Pollution" by Prof. M. C. Whipple of Harvard University.

Prof. Gordon M. Fair of Harvard spoke on "New Developments in Sewage Treatment in Germany." His talk was accompanied by many interesting slides depicting the new developments in sewage treatment in that country.

In preparation for the excursion to the Brockton Sewage Treatment Works on the following day, Mr. F. H. Kennedy, City Chemist of Brockton, described the plant in detail.

The following officers were elected for the ensuing year: *President*, Stuart E. Coburn, Boston; *First Vice-President*, Julius W. Bugbee, Providence; *Second Vice-President*, Warren J. Scott, Hartford; *Treasurer*, Roscoe H. Suttie, New Haven; *Secretary*, F. Wellington Gilcreas, Boston.

The annual dinner of the Association was held at the Hotel Brunswick. At the close of the dinner, motion pictures, "Sewage Disposal," showing the operation of the Brockton Sewage Treatment Plant were presented, after which the meeting was devoted to a round table discussion on the following topics:

Maintenance tools and how to use them.
Troubles with oil and grease.
Screenings and what to do with them.
Sand filters and their operation.
(*a*) What do you think of fixed distributors?
(*b*) What is your practice in winter furrowing?
How to add lime to sludge digestion tanks.
Sewer maintenance.

On Wednesday morning, April 16th, fifteen members of the Association traveled by automobile to Brockton to inspect the Brockton Sewage Treatment Plant. Mr. Crocker and Mr. Kennedy guided the party through the plant, explaining in detail the operation of the various parts of the entire plant and the pumping station. The party was greeted at the pumping station by Mayor Brent of Brockton and members of the Sewer Commission. Following the inspection of the plant, the City of Brockton entertained the members of the party with a delicious luncheon on the grounds of the treatment plant. After lunch the party returned to Boston to attend the joint meeting of the New England Health Institute and the New England Water Works Association held at the Hotel Statler.

Reviews and Abstracts

H. W. STREETER

Generation of Heat by Sewage Sludge

By Dr. Herman Bach, Chief Chemist, Emschergenossenschaft

Technisches Gemeindeblatt, **33**, 108–112 (May 20, 1930)

Abstracted by G. P. Edwards

During 1928 and 1929, Drs. Prüss and Fries published articles on the value of different types of construction and operation of sludge digestion tanks in which they differed in opinion as to the question of the heat generated during the digestion. Fries assumed that the self-heating of sludge might effect a possible heat economy in the sludge-digestion chamber—comparing the generation of heat to that in a manure pile. Prüss, on the basis of temperature measurements made at treatment plants of the Emschergenossenschaft for some time, estimated the heat generated by the sludge to be only about 100–150 large calories per cubic meter per day. A large calorie is the amount of heat necessary to raise the temperature of 1 kg. of water 1° C. At best, then, the temperature of 1 cu. m. of sludge would be raised about 0.15° C. daily if the heat coefficient of the sludge is the same as water. Prüss calculated the heat losses to be about 250 W. E. per cu. m. per day in a well-insulated sludge tank so that the heat lost would exceed the heat generated. If, however, the heat generated by the sludge is considerable, it might be possible to use a correspondingly smaller amount of artificial heat to maintain the proper temperature. According to Prüss, this daily temperature increase of about 0.15° C. would amount to about 9° C. during a sixty-day accumulation.

In general, the synthesis of organic compounds of high molecular weight is an endothermic reaction, taking up heat, while the decomposition of compounds of high molecular weight is an exothermic reaction, giving off heat. Both processes take place during sludge digestion. Protein and other organic compounds of high molecular weight decompose while the new bacterial life synthesizes new compounds. The synthetic processes, however, are of little importance.

During the digestion of sludge, all of the solids do not enter into the reaction which furnishes the heat, and the gas formed contains latent heat which is not available for self heating. At best, only a fraction of the reaction heat may be of use for heating of the sludge room. If the digestion of sludge were a single simple process, the calculation of this

fraction would be relatively simple. Since the reactions are very complex, the establishment of upper and lower limits may aid in the calculation. In this case, the lower limit is zero and the upper limit may be obtained by combustion of the sludge in a calorimeter.

Samples of fresh sludge from two Emschergenossenschaft plants and from the Munich treatment plant were dried on a water bath and the calorific value obtained as shown in Table I.

TABLE I

COMPOSITION OF DRY FRESH SOLIDS AND CALORIFIC VALUES

Sample	1 Fresh Solids from Essen-Frohnhausen	2 Fresh Solids from Essen-Frohnhausen	3 Fresh Solids from Essen-Nord	4 Fresh Solids from Essen-Nord	5 Fresh Solids from Munich
Dry solids contained %:					
Mineral	32.2	39.2	53.8	39.4	29.4
Organic	67.8	60.8	46.2	60.6	70.6
Heat value of dry solids large calories	3690	3860	2810	3660	3710
Heat value per kg. organic matter	5460	6350	6080	6040	5250

The heat is due to the combustion of organic substances. The values vary between 5250 and 6350 large calories per kilogram organic matter. The Emschergenossenschaft samples were higher because of the presence of industrial wastes. According to these analyses 6500 large calories can be assumed as a maximum from fresh solids.

In considering this theoretical heat content of the organic solids, the water and mineral content must be taken into account. In sludge from the separate sludge-digestion tanks of the Emschergenossenschaft which have been in continuous operation, there is an average of about 82 per cent water. If the mineral content of the dried sludge is assumed to be about 35 per cent, 1 cu. m. of sludge would contain 920 kg. water, 28 kg. mineral matter and 52 kg. of organic matter, giving a total latent heat of 337,000 large calories. (In order to simplify the calculations, the specific gravity of the sludge and solids is considered to be 1.)

The theoretical amount of latent heat furnished by the organic matter of the sludge would amount to about 337° C. per cubic meter of sludge. If this amount of heat is divided into 60 days, the average daily increase would be about 5.6° C. With a water content of 95 per cent, there would be an average increase in temperature of only about 3.5° C.

In order to determine what fraction of this ideal basic heat value is available, it must be considered that:

(*a*) During the digestion process, gas with a high heat value escapes:

(*b*) After the completion of sludge digestion, part of the sludge which contains organic matter and which has not given up its heat, remains.

(*c*) A part of the organic matter which has not given up its heat equivalent is removed with the digestion room liquor.

The theoretical amount of heat available is therefore decreased by the amount of gas formed, by the amount of organic matter remaining in the digested sludge and by the organic matter escaping with the sludge liquor.

The gas from sludge digestion has a heat value of about 5000 to 7000 large calories. There is also a considerable amount of latent heat remaining in well-digested sludge. An average sample of dry well-digested sludge from Munich contained 46.9 per cent mineral and 53.1 per cent organic matter. Measured in a calorimeter 2260 large calories were liberated when the sludge was burned. Values obtained from treatment plants of the Emschergenossenschaft show that digested sludge contained from 74.2–92.2 per cent water and that the organic matter in the dried sample varied from 41.2–73.8 per cent organic matter. Heat values per kilogram of organic matter ranged from 5360–7920 large calories.

The quantity of heat generated during sludge digestion can be determined only by means of a careful heat balance which should include the amount and heat value of fresh sludge as well as the amount and heat values of the digested sludge, the sludge liquor and the gas. These measurements and determinations should be carried on for at least two years.

TABLE II

DIGESTION OF A SLUDGE SAMPLE FROM ESSEN-FROHNHAUSEN

	Fresh Solids	Digested Sludge	Gas 2835 cc. Average composition in % by volume	
Dry solids	7.50 gr.	7.50 gr.	CO_2	29.3
Organic solids	4.56 gr.	1.63 gr.	CH_4	57.2
Heat value of the dried sludge	3860 Cal.	2265 Cal.	H_2	4.1
Heat value based on organic matter used	28.5 Cal.	10.2 Cal.	N_2	9.4
Heat value of gases of digestion			5880 Cal./cu. m.	
Heat value of gases obtained			16.6 Cal.	

In a laboratory experiment, a sample of fresh sludge from Essen-Frohnhausen was analyzed and the heat values obtained. One hundred cc. of this sludge was mixed with 500 cc. conductivity water in a glass flask fitted with a gas collection tube. The contents of the flask were shaken once daily to aid the digestion. The sludge was digested at room temperature for $5^1/_2$ months. At the end of that time, gas formation had stopped and the sludge was more completely digested than is feasible in a technical plant. The gas and digested sludge were analyzed. The results are shown in Table II.

This heat balance shows that of the original 28.5 Cal., 16.6 Cal. were carried away in the gas and 10.2 Cal. remained in the sludge. A considerable portion of the remaining 1.7 Cal. was in the sludge liquor since some of the decomposition products are soluble. Under favorable conditions, about 1.2 Cal. or 4 per cent of the heat content of the fresh sludge would be free for heating the digestion tank. If the maximum heat value of the organic matter, which forms 65 per cent of the dried fresh solids, is assumed to be 6500 Cal. and the water content is 92 per cent, then there would be about 13,500 Cal./cu. m. available for self-heating or the total amount of heat given off would be 13.5° C. In a 60-day digestion period, this would average only about 0.225° C. per day. This value is approximately the same as that obtained by Prüss.

In an attempt to measure the heat generated by a direct method, two large filtering jars were placed side-by-side in a protected place in the laboratory. Ten liters of water were added to one jar and ten liters of fresh sludge from Essen-Frohnhausen were added to the other. A thermometer graduated to 1/10° C. and carefully checked as to accuracy was hung exactly in the center of each jar. The temperature of the room varied during the experiment about 5° C. The temperature of the water and sludge rose and fell with the temperature of the room. Occasionally there was a difference of temperature in the water and sludge of 2° C. This had nothing to do with the self-heating of the sludge because the water often became warmer than the sludge. For two weeks during the beginning of the experiment the room temperature remained constant. During this time the temperature of the sludge and the water varied only about 1/10° C. This experiment could be carried out more accurately in a constant temperature room but the results obtained indicate that no appreciable amount of heat was generated.

Conditions are quite different in a manure pile. There the action is aerobic and the organic matter is oxidized to carbon dioxide instead of methane. Manure is also more or less porous and bulky. The more porous the organic digestible material is, the greater the amount of heat formed. The temperature in a damp hay pile sometimes rises to the ignition point. The self-heating of sludge cannot be compared to these processes. From the results of the experiments, the heat generated during the digestion of sludge could raise the temperature only a fraction of a degree Centigrade and could play no important part in the heat economy of a digestion tank.

Efficiency and Cost of Sewage Disinfection

BY J. W. ELLMS AND G. T. POND

Municipal Sanitation, 1, 266–268 (May, 1929)

ABSTRACTED BY H. GLADYS SWOPE

During the summer months, June, July, August and part of September, the effluents from Cleveland's sewage disposal plants are treated with chlorine.

Cleveland's sewage is only partially treated. At the Westerly plant, which comprises coarse bar screens, grit chamber, and sixteen Imhoff tanks, the wastes are both domestic and industrial and average about 30 million gallons per day. The sewage at the Easterly plant is primarily domestic and is very incompletely treated, the plant comprising only coarse bar screens and grit chamber. This plant handles 90 m. g. d.

The average analyses of raw sewages and effluents from 1923–1929 inclusive have been tabulated. The average results over this entire period were:

RESULTS IN PARTS PER MILLION

	Total Solids E.	Total Solids W.	Suspended Solids E.	Suspended Solids W.	Settleable Solids* W.	Ox. Cons. E.	Ox. Cons. W.	Chlorides E.	Chlorides W.
Raw	629–1113		172–202		6.0	59–74		64–107	
Effluent	632–1027		178–120		0.3	60–65		64–109	

* Cc. per liter, 2 hours settling.

From 1923–1928, inclusive, the chlorine was drawn from 150-lb. cylinders, which were placed in a wooden tank through which warm water was circulated. In 1929, the plants were equipped with large evaporators for converting liquid chlorine, drawn from ton containers or 15-ton tank cars, into chlorine gas. This resulted in a 40 per cent reduction in cost of disinfection.

During the seven years an average of 7.91 p. p. m. of chlorine was applied at the East side plant and 8.71 p. p. m. at the West side plant. At the Easterly plant 55.3% of the samples showed residual chlorine, but only 31.5% at the Westerly plant.

The average reduction from 1924–1929 inclusive in total bacteria counts at 37° C., presumptive *B. coli*, and 5-day B. O. D. at 20° C., was 93.4, 96.1 and 18.6 per cent, respectively, at the Easterly plant and 80.5, 85.9 and 17.5 per cent, respectively, at the Westerly plant.

The average cost for disinfection during these six years was $27,835.36 at the East side and $10,662.90 at the West side, or $3.86 and $5.07 per million gallons, respectively.

The industrial wastes present in the sewage treated at the Westerly plant reduced the effectiveness of chlorine disinfection.

The Chlorination of Sewage

BY DR. K. VIEHL, SEWAGE TREATMENT WORKS, LEIPZIG

Vom Wasser, p. 219 (1929)

ABSTRACTED BY G. P. EDWARDS

Since Leipzig spends about $50,000 annually in chlorinating sewage, scientific methods are desirable to obtain the best results. Sewage with low chlorine demand should show free chlorine with *o*-tolidin after ten minutes.

Disinfection with chlorine is accomplished more rapidly in sewage with a high chlorine demand than with a low one. The resulting chlorine compounds are germicidal, so that in water with a high chlorine demand the number of bacteria is sufficiently reduced if a positive reaction is obtained after ten minutes with starch or dimethyl-*p*-phenylene diamine. These compounds indicate certain oxidation products and chlorine compounds which result from the chlorination of sewage to which *o*-tolidin is not sensitive. About 10 gr. chlorine per cubic meter less is needed to obtain an excess with these indicators than with *o*-tolidin.

The chlorine demand at Leipzig varies from 8 to 50 gr. per cu. m. It is remarkable that the chlorine demand curve runs more nearly parallel to the oxygen consumed curve than to the chlorine number curve, whose maximum appears at a different time of the day. In summer, the chlorine demand is generally greater than at other times of the year. The number of bacteria in suspended matter is reduced by chlorination to about 1000 per cc. provided that the suspended matter is not too coarse. The chlorine demand of a sewage flowing through a settling tank may increase because of mixture with liquid from the digestion chamber. Prechlorination avoids this condition and eliminates odor by reducing hydrogen sulphide to less than 0.5 part per million. Prechlorination for activated sludge removes the hydrogen sulphide and slightly increases the nitrite and nitrate. The aeration period cannot be reduced by chlorination.

In order to determine the effect of chlorination on plankton, sewage with a chlorine demand of 40 p. p. m. was treated with 37 p. p. m. of chlorine. The mixture was positive to starch KI and dimethyl-*p*-phenylene-diamine and negative to *o*-tolidin. This sewage was mixed with an equal quantity of river water which contained plankton. In an hour, all paramecia except those enclosed in sewage clumps were dead. In twenty hours, all the ciliates, most of the rotifers and fly larvae were dead, while mosquito larvae, cyclops and Daphnia were still alive. The results were nearly the same in a mixture of three parts of river water with one part of chlorinated sewage.

Superchlorinated sewage was mixed with different amounts of un-

chlorinated sewage. Results of bacterial counts showed that there is little difference whether part of the sewage is superchlorinated and then mixed with the remainder or whether the same amount of chlorine is added to the total volume of sewage.

Chlorine had no coagulating effect on colloids. It did not aid settling either in secondary settling, activated sludge or preliminary settling tanks.

During discussion of the paper, Viehl stated that superchlorination of the sewage to kill algae in the river was not practical because of the large amount of chlorine necessary. Sewage algae growths are sometimes found 20 km. downstream from the sewer outfall. The large dosage of chlorine necessary could not be used because of the high cost and because of the harm to the self-purifying agencies in the river.

Mieder (Leipzig) reported a great deal of sewage algae, especially *Leptomitus lacteus* in the Elster and Luppe Rivers before the use of sewage chlorination. During the winter months, as much as twenty truck loads per day have been removed from the coarse screens of the Lütschena Power Works (5–6 km. below the city) whereas after chlorination only one-half to one load per day was collected.

Grevemeyer (Charlottenburg) recommended that superchlorination should be carried out under careful supervision so as to avoid injury to fish.

Ebeling (Berlin-Friedrichshagen) stated that results obtained by the "Landesanstalt für Fischerei" showed that amounts of free chlorine in excess of 0.1–0.2 p. p. m. maintained in a stream for several days were toxic to fish. This toxic action of free chlorine is greater at low temperatures such as 4–6° C. than from 10° C. up.

Ornstein (Berlin) reported that copper or a copper salt used with chlorine is much more effective as an algaecide than either copper or chlorine alone. When algae must be removed from a badly polluted river so as to make the water suitable for industrial purposes, the results obtained with an average of 2.5 p. p. m. chlorine and 0.18 p. p. m. copper are as satisfactory as with 20 p. p. m. chlorine and better than with 100 p. p. m. copper sulphate.

The Chlorination of Beet Sugar Wastes

BY DR. H. PICK, AUSSIG

Vom Wasser, p. 246 (1929)

ABSTRACTED BY G. P. EDWARDS

The Wischau Sugar Factory in Mähren like many other factories has investigated the chlorination of its wastes for the purpose of using them again in the process, because of the insufficient supply of fresh water.

The Wischau factory discharges about 14,000–15,000 cubic meters of water daily, not including the condensate. The acid waste is not separated from the diffusion and beet wash water. The total amount of waste is treated with lime and humin, settled and filtered through cinder filters. When there is a scarcity of water, part of the effluent from the filters is pumped back to the factory. During part of the year, the streams Rosternitz and Trnowitz have a flow of only 20 liters per second, which resembles in odor and color sewage more than water.

As it was impossible to separate the acid waste from the organic waste, chlorination was provided for the effluent from two preliminary clarification tanks. The secondary clarification was reduced to a minimum so as to hasten the circulation of the water as much as possible.

Before chlorination began, water was very scarce, and part of the plant effluent was pumped back for use in the factory. This liquid contained a great deal of soluble organic matter. The addition of lime was increased to maintain a minimum alkalinity of 0.02 per cent. The warm weather encouraged digestion in the secondary tanks and the waste quickly became black and foul smelling. The cattle would not drink the water.

On the 24th day of the season, 50 grams of chlorine were added per cubic meter of sewage. Digestion stopped and the waste was fresh on its entrance into the Rosternitz stream. The chlorination was reduced to 6 gr. on the second day and then to 5 gr. per cu. m. during the rest of the season. A small amount of free chlorine was maintained in the entire system. During the chlorination, the addition of humin and lime were greatly reduced, resulting in a saving of more than the cost of chlorination.

Studies on the Treatment of Milk Products Wastes

BY E. F. ELDRIDGE

Bulletins 24 and *28*, Michigan Engineering Experiment Station, East Lansing, Michigan

ABSTRACTED BY KATHLEEN MEAGHER

During 1929 and 1930 experimentation on the treatment of milk products waste has been carried on by E. F. Eldridge of Michigan State College, and the results are reported in Progress Reports 1 and 2 issued July, 1929, and March, 1930, respectively. The methods selected for study were chemical precipitation, biological filtration of effluent from chemical precipitation, biological treatment of raw waste on sand filters and biological treatment of raw waste on gravel filters. Only a portion of the waste, which was equivalent to 1.66 per cent solution of whole milk, was used for the treatment experiments so no measurements of the total volume were made. The analysis of the milk used is given below:

ANALYSIS OF WHOLE MILK AND BY-PRODUCTS

	Whole Milk	Skim Milk	Butter Milk	Whey
Total solids	12.5%	8.23%	7.75%	7.20%
Organic solids	11.7	7.45	6.88	6.40
Ash	0.80	0.78	0.87	0.80
Fat	3.6	0.10	0.50	0.40
Sugar	4.5	4.60	4.30	4.40
Protein	3.8	3.9	3.6	0.8
B. O. D. (5-day)	102,500 p. p. m.	73,000 p. p. m.	64,000 p. p. m.	32,000 p. p. m.
Ox. cons.	36,750	32,200	28,600	25,900

The experimental plant used for chemical precipitation consisted of a sump, centrifugal pump, storage tank, orifice box, two fill-and-draw tanks, one flowing-through tank, concentration tank and sludge bed. Dosing was accomplished by means of a nozzle of the sprinkler type. The chemicals used most successfully were ferrous sulphate and lime, between two and six pounds per thousand gallons of the former and one and five pounds of the latter. The proper alkalinity was maintained by phenolphthalein control, but careful control of the operation of the tank was necessary since the pH of the waste varied from above 9.0 to as low as 4.0. Concentration of the sludge resulted in reductions in volume of from 65 to 70 per cent, reducing the drying bed area in the same proportion. The oxygen-consumed determination, which was used to indicate the efficiency of treatment, under optimum conditions showed a reduction of 40 to 48 per cent. The disadvantages of this method were high cost of plant construction, operation and maintenance, unstable effluent, difficulty in application of chemicals and in disposal of sludge.

A filter 10 ft. in diameter and 10 ft. deep filled with graded gravel $1^1/_2$ to 3 inches in size was used for the effluent from chemical precipitation. It was operated on a 12-hour period from December 13, 1928, to March 18, 1929. The efficiency of the filter seemed to follow the temperature curves. The average reduction in oxygen consumed value during cold weather was about 40 per cent. In March, during warm weather, the efficiency reached 89 per cent reduction. The effective depth of the filter was about seven feet.

Where sand is abundant biological treatment of raw milk waste on a sand filter is satisfactory. The filter consisted of a barrel filled to a depth of 30 inches with sand of the type used to make concrete and was dosed four times daily—8:00, 11:00, 2:00 and 5:00—by means of a bucket at rates from 30,000 to 230,000 gallons per acre per day. A rate of 200,000 g. a. d. was found to be the maximum for efficient oxidation under optimum conditions. As the strength of the waste increased the rate of application had to be decreased. At rates of 150,000 and 200,000 g. a. d. the maximum B. O. D. of the waste was 1500 and 1400 p. p. m., respectively. Higher rates

with lower B. O. D. are preferred to low rates and high B. O. D. because of the tendency of the strong waste to decompose on the filter. Clogging of the filter, due to the removal of solids, limits the use of sand as a filter medium to localities where land is plentiful, suitable sand is available at low cost and labor is relatively cheap.

The dosing tank and filter, composed of graded gravel ($1^1/_2$–3 in.), were the same as those used for treatment of effluent from chemical precipitation with the exception that the sprinkling type nozzle was replaced by a revolving arm sprinkler which gave better distribution of the waste over the filter. Owing to the small quantity of waste intermittent dosing of $1^1/_2$ minutes dose and 3 minutes rest was employed satisfactorily over a 12-hr. day. Wastes with a B. O. D. of 1600 p. p. m. were successfully treated at the rate of 1,000,000 g. a. d. on a 10-ft. filter, effecting a reduction as high as 93 per cent, 80 per cent of which was obtained in the first six feet of filter. There was a corresponding decrease in suspended solids, if the inorganic material of the water is not considered. Most of the acid-producing compounds were oxidized in the first four to six feet. Nitrite production reached its peak at about the 8-ft. level with waste having 1600 p. p. m. B. O. D. Nitrates increased throughout the filter in both upper and lower portions. The effluent from this filter was clear, fairly stable and fit to discharge into a small stream.

Studies were made of brush and cinders as filter media when gravel and stone are not available. Brush was not successful because it was difficult to pack it sufficiently to prevent drying out at night when no waste was being applied, thus preventing the development of bacterial slime and inducing rotting of the brush. The cinder filter was enclosed in a box 4 ft. square and 8 ft. high. The waste was applied by means of an orifice box and tipping trough at the rate of 1,000,000 g. a. d. Average reductions of B. O. D. of 52, 70, 81 and 89 per cent, respectively, were obtained at the 2, 4, 6 and 8-ft. levels. The acid-producing compounds were oxidized in the first 2 to 6 feet. Wastes up to 1740 p. p. m. B. O. D. were successfully oxidized. A large quantity of solids were retained on the filter and no unloading took place during the time of operation which often occurred in the operation of the gravel filter. Chlorination of the filter might be necessary at times to start the unloading.

The advantages of biological filtration as compared with chemical precipitation of milk wastes are reasonable cost of construction and operation, ease of control, high reduction in oxygen demanding materials and removal of sugars to prevent souring of effluent. The disadvantages of this type of treatment are the space required for filters, and the necessity of housing filters if they are to be operated during the winter months.

Further studies during the summer of 1930 will include experimental work on the effect of aeration of the raw waste in the storage tank before

applying to the filter, on the rate of application and strength of waste which can be applied; the effect of milk waste in sanitary sewage; the study of construction costs under local conditions; and the study of factory conditions to determine the average milk solids losses and strength of milk waste under average conditions of plant operation.

Removal of Milk Constituents by Filtration

BY MAX LEVINE, GEO. W. BURKE AND J. H. WATKINS

Bulletin 95, Engineering Experiment Station, Iowa State College, Ames, Iowa

ABSTRACTED BY THE AUTHORS

The efficiency of an experimental lath filter (6 ft. deep) for the removal of milk constituents from dairy wastes applied at a rate of 800,000 g. a. d. for 10 to 14 hr. daily, was observed. The liquors employed consisted of skim-milk-powder dilutions equivalent to 0.5 to 7.0 per cent skim milk, simulating butter factory wastes, and a milk-powder solution to which was added various concentrations of lactose, simulating cheese factory wastes. The construction of the filter was such as to permit a study of the relative efficiencies of different depths of filtration.

The upper two feet of the filter were particularly effective in the removal of solids, organic nitrogen, and oxygen-consuming constituents, generally accounting for over 80 per cent of the total reductions effected by the entire depth (6 ft.) of filtration.

The proportion of milk constituents removed rose with increasing concentrations of the applied wastes. There were obtained reductions of 38, 54 and 32.2 per cent in solids, oxygen consumed and organic nitrogen, respectively, when employing a waste equivalent to 0.5 per cent skim milk, whereas with the 7.0 per cent waste the corresponding reductions were 89.4, 94.4 and 90.4 per cent.

Effluents showing relative stabilities of over 90 per cent were obtained with concentrations of the applied wastes up to 1 per cent skim milk.

The filter was very efficient as regards the destruction of milk sugar without development of acidities. Wastes containing up to 3500 p. p. m. of lactose yielded sugar-free effluents which remained alkaline on anaerobic storage.

The trickling filter appears to be a feasible means of partially treating creamery wastes so as to produce effluents which may be discharged into municipal sewage without danger of development of detrimental acidities in the municipal sewage disposal plant.

Flat Bottom Tanks with Sludge Removal Apparatus

BY DR. ING. MAX PRÜSS

Gesundh. Ing., **53**, 278 (1930)

ABSTRACTED BY G. P. EDWARDS

The appliances for removing sludge from flat bottom tanks may be grouped into the following types:

1. Scrapers which are used in narrow rectangular tanks and which operate on a revolving chain forcing the sludge to the influent end.
2. Scrapers which force the sludge to a sump at the influent end and then return at the surface of the liquid.
3. Scrapers moving in a circle which force the sludge to the deepest point in the center of a round or square tank.

Circular tanks with radial flow fitted with circular scrapers to force the sludge to the center are the most satisfactory type.

In 1928, a tank about 98 ft. in diameter with circular scrapers was built at the Essen-Nord plant of the Emschergenossenschaft to relieve the Imhoff tanks from their heavy load. The average flow is about 150 gal. per second from about 180,000 inhabitants. The sewage contains large amounts of iron-pickling waste and about 900 cu. yd. of light sludge are obtained daily. Deposition of such large quantities of sludge in the Imhoff tanks caused displacement of considerable quantities of black sludge liquor into the effluent. In the new tank the sewage is carried to the center by a siphon. On entering the tank the velocity is decreased by vertical wooden racks. All heavy particles such as sand—the plant has no grit chamber—sink through the slots directly into the lower collection tank. This chamber is unusually large (about 1050 cu. yd.) because of the large amount of very light sludge. Only the lightest sludge reaches the bottom of the settling tank and is forced by the scrapers through the slots into the control chamber. The thickened sludge is removed once daily.

The mines under the city cause uneven sinking of the land, therefore at Essen-Nord the scrapers have been jointed in such a way that they can move freely over the floor. These movable scrapers are attached to floating pontoons and can be raised above the surface for repairs without putting the tank out of operation. Four hours' operation daily is sufficient to remove the sludge. The scrapers make four revolutions per hour and the power required is less than 1 kw. hour. The floating part of the scraper easily collects the scum which rapidly becomes septic and causes disagreeable odors. The scum is removed once or twice daily and forced into the sludge collection chamber.

The cost of constructing a new plant with about 1700 cu. yd. settling

space and about 1050 cu. yd. sludge collection space is about 180,000 marks ($45,000) including the machinery.

By collecting and storing the sludge for some hours in the sludge collection room, the water content which is initially about 98 per cent, decreases to about 88–90 per cent as compared with 96–97 per cent from the ordinary settling tank.

A new tank about 150 ft. in diameter and 10 ft. effective depth will be built by the Emschergenossenschaft. In order to facilitate sludge removal, the scrapers will be built in two sections. The inner part of the scraper can move as fast as is necessary for removing the sludge, whereas the outer section will move very slowly. Only the sludge from the inner 115 ft. diameter will be collected in the center tank. The small amount of light sludge sinking to the bottom at the edge will be scraped together to outer sludge collection tanks from which it will be forced to the center tanks and mixed with heavy sludge. The scrapers will be moved by a light movable crane running on a track. Only one or two revolutions daily at a speed of one revolution every two hours will be necessary. Wooden racks placed where the sewage enters the tank will slow down the rate of flow and aid settling.

Tanks 200 ft. or more in diameter could be satisfactorily built and operated with this arrangement. It would be particularly suitable for activated sludge since the sludge from the center tank, remaining only a short time without air, could be returned to the aeration tank and the sludge from the outer ring could be wasted.

Recent Works for Purification of Trade Refuse

BY J. H. GARNER

Report of West Riding of Yorkshire Rivers Board,
Wakefield, England, April, 1930

ABSTRACTED BY H. GLADYS SWOPE

This report comprises a description of the treatment works erected at Thirstin Mills, Honley, and Nutclough Mills, Hebden Bridge. The Dortmund (upward-flow) type of settling tank is also described.

The purification works at Thirstin Mills, Honley, were put into operation in 1924. The wastes treated are those from the piece-scouring and dyeing processes, during the manufacture of light woolen cloth. These wastes average 70,000 Imp. gallons per 10-hr. day. Preliminary experiments indicated that the wastes could be effectively treated by chemical precipitation, using alumino-ferric.

The purification works consist of an averaging tank, two sedimentation tanks, and five sludge filters.

The waste liquids from any textile mill are irregularly discharged. To ensure satisfactory operation, an averaging tank was constructed for equalizing the composition and rate of flow of the wastes. This tank was 50 ft. long, 9 ft. wide and 9 ft. deep, having a capacity of 25,000 gallons. A special feature is the averaging valve, which is a short floating-arm decanting pipe and valve so set that the wastes are delivered uniformly to the settling tanks throughout the day. There is an emergency overflow pipe, near the top of the averaging tank, which delivers into the feed channel of the sedimentation tanks.

The sedimentation tanks are 50 by 13 by 6 feet, having a total capacity of 48,750 gallons. The tanks are fitted with floating-arm pipes and valves for decanting supernatant water previous to sludging; this water can be discharged directly to the stream or to the straining filters, if necessary. The effluent from the averaging tank flows over blocks of alumino-ferric placed in the feed channel to the sedimentation tanks. The waste waters enter the settling tanks through two cast-iron rectangular hand-stops fitted with catches for adjusting the rate of inflow by means of the stop-plates. The effluent flows over weirs extending the full width of the tanks, and is discharged into a stream.

Both the averaging and settling tanks are fitted with baffle walls placed about $^1/_4$ of the length of tank from the inlet ends. These baffle walls increase the rate of sedimentation by deflecting the waste waters toward the bottom of the tank.

Each of five filters or sludge-drying beds is 50 by 10 ft. with a total area of 2500 sq. ft. The floors and sides of the beds are of lightly reinforced concrete. The filter medium consists of a lower layer of broken brick (depth $3^1/_2$", grade 8" to 4"), then 4" of hard clinker, grade 2" to 1", then 4" hard clinker, grade $^1/_2$" to $^1/_8$", and for top layer 1" of fine material of $^1/_8$" grade. Sludge is run onto the filters to a depth of one foot.

The Nutclough Mills, Hebden Bridge, manufacture light and heavy cotton piece goods. Their wastes, amounting to 90,000 gallons per 10-hr. day, are from the dyeing, bleaching, stiffening and desizing processes. The greatest volume comes from the dyehouse. These wastes are chiefly from sulphide and basic colors and sodium hypochlorite used in the bleaching process.

The sulphides are removed by filling a perforated barrel or drum with ferrous sulphate, placing this over the main refuse drain and allowing a small spray of water to trickle continuously over this drum.

The treatment plant comprises two averaging and sedimentation tanks and two sludge beds.

The waste flows through the refuse drain where it receives its dose of ferrous sulphate solution, then to the averaging tanks. Compressed air is forced through a number of perforated iron pipes in the floor of the tanks.

This keeps the waste in a continual state of agitation, thus ensuring thorough mixing and preventing deposition of solids.

An electrically driven centrifugal pump lifts the waste from the averaging tanks to the settling tanks. These two tanks, used in parallel, have a total capacity of 34,500 gallons. They are 17 feet deep at the inlet end and the outlet is over a weir extending the full width of the tanks. The floors of the tank slope upward, at first gradually, from the inlet to the outlet end. The sides of the tanks at the inlet end also slope toward the center. The incoming liquid passes into a shallow open channel, then through 4-inch pipes and downward behind a baffle wall, extending within $4^1/_2$ ft. of the bottom of the tank, and the liquid then rises slowly as it flows through the tank. These conditions are very favorable for deposition of the solids.

The area of the sludge beds is 680 sq. ft. These sludge filters are constructed as were those at the Thirstin Mills. The sludge dries in two or three weeks.

The Dortmund, upward-flow type of settling tank is very completely described. The upper part of the tank is square and the lower portion is an inverted pyramid, terminating in a small sump with vertical sides. By having a pyramidal bottom (slope of 60°), the sludge can be removed by hydrostatic pressure, with little or no interruption of the operation of the tank and without drawing off the supernatant liquid. The flow through the inlet pipe, which discharges through the up-turned end just below the water surface, should not be less than 1 foot per second. The inlet pipe should be surrounded by an iron or wooden tube dipping well below the water level of the tank. As the liquid emerges from the bottom of the tube, it spreads out laterally and rises in "stream-line" flow at a gradually decreasing velocity to the surface level, at which the settled liquid escapes over weirs around the whole length of the sides of the tank, so that the velocity of exit is reduced to a minimum.

It is not advisable to construct upward-flow tanks larger than 25 square feet. The average rate of upward flow of 44 tanks in West Riding is 1.3 ft. per hour. For trade wastes containing flocculated solids 2 feet per hour is best.

Computations are included for determining the number and size of upward-flow tanks required for a given sewage flow.

Akron's New Sewage Plants

BY T. C. SCHAETZLE

Municipal Sanitation, 1, 376–381 (July, 1930)

ABSTRACTED BY H. GLADYS SWOPE

Akron, with a population of 260,000, has two sewage treatment plants. The old plant was put into operation in July, 1916. It includes twelve Imhoff tanks and four acres of slag trickling filters. This plant could handle only 4.1 m. g. d. in 1929, as compared with 19.7 m. g. d. treated by the new plant, which was completed in December, 1928.

The new plant consists of bar screens, fine screens, two grit conveyors, and two Dorrco revolving screens; two circular Dorr detritus tanks provided with grease-skimming boom; 24 reversible-flow Imhoff tanks; 14 acres of trickling filters, 10 ft. deep; 12 humus tanks, 4 acres of sludge beds and an administration building. The sewage passes through the bar screens into the detritus tanks where a detention period of fifteen minutes is obtained with a flow of 33 m. g. d. Eighty per cent of the flow passes out through rising gates to the Imhoff tanks. The remaining twenty per cent is pumped to the grit channels, then through the Dorrco screens after which it is mixed with the other 80 per cent. The Imhoff tanks provide a settling period of two hours and 2.77 cu. ft. per capita sludge storage for a flow of 33 m. g. d. The sewage contains concentrated wastes from rubber reclaiming plants. In spite of the skimming arrangements in the detritus tanks, a very fine brown film formed in the Imhoff tanks. The Imhoff sludge did not digest rapidly, probably because of the rubber wastes and the fact that the plant was started in the winter. The average pH of the sludge for 1929 was 5.9. No foaming difficulties were encountered except in a tank which was limed. It required 3 tons of lime to raise the pH to 7.1. The humus tank sludge, when introduced into the flowing-through compartment, formed a tenacious scum.

Slight pooling and low nitrification have been the outstanding difficulties with the trickling filters. The black, rubbery film on the stones can be removed by harrowing and it is believed that the film will decrease in time. The average rate of filtration has been 1.63 m. g. a. d.

The average analyses from June to December, 1929, were as follows for the raw sewage and final effluent, respectively: suspended solids, 302 and 46 p. p. m.; 5-day B. O. D., 131 and 15.4 p. p. m.; nitrate nitrogen, 0.0 and 2.3 p. p. m. The digested sludge applied to the beds contained 85.3 per cent water, and 57.5 per cent as removed. A long period of 52 days was required for drying.

Removal of partial treatment of the rubber reclaiming wastes will greatly improve the conditions of operation.